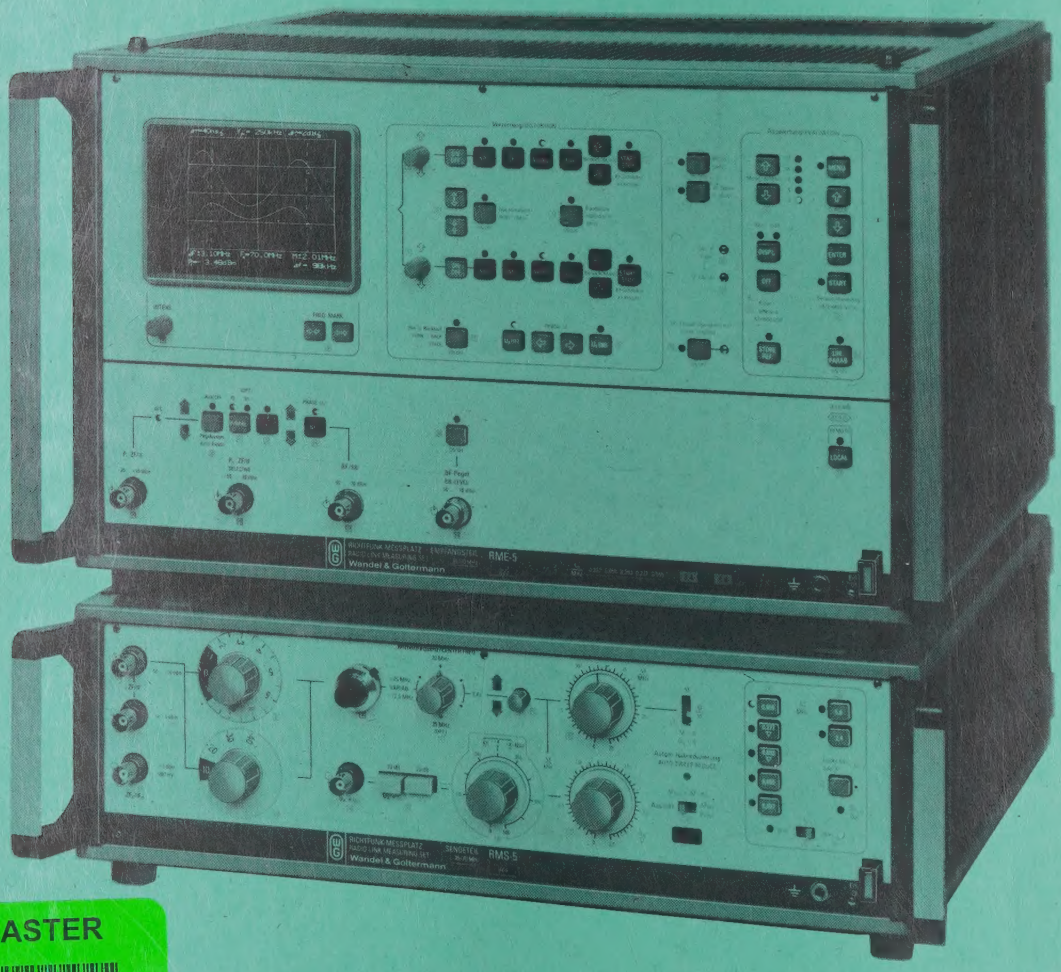
Description and
Operating Manual



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Radio-Link Measuring Setup 35/70 MHz RM-5

for distortion measurements on radio-link and satellite systems

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Description and
Operating Manual BN 916/917, Series A

Order No. BN 916/00.82
Edition 3059

I.5.83 Loe/Ar
0.25.5.83

Subject to change without notice
Printed in the Federal Republic of Germany

Wandel & Goltermann

PRECISION ELECTRONIC
MEASURING INSTRUMENTS

C O N T E N T S RM-5

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INTRODUCTION

The intermediate frequency (IF) of 70 MHz will in future become more important, as systems with small numbers of channels for which a higher IF than 70 MHz is uninteresting will become more popular alongside the classical "1800 channel radio relay systems". The Radio-Link Measuring Setup RM-5 takes this fact into account, as it is equally suitable for measurements on narrow and wideband systems with its intermediate frequency of 70 MHz (35 MHz as an option).

With the aid of the Radio-Link Measuring Setup RM-5, which consists of separate Generator RMS-5 and Receiver RME-5, it is not only possible to measure and display the total distortion in the baseband (BB) in a simple manner, but also to determine the ports distortions between IF individual, of system modulators and demodulators, and of IF filters. Only the combination of facilities permits simple localization of faults and alignment both of single subassemblies and of complete systems.

The intermodulation method generally used in radio-link distortion measurement for detecting nonlinearities in the signal path of the frequency-modulated signal is also the principle used in the RM-5. For this method, the generator generates a low frequency sweep voltage U_A with a large amplitude and a high frequency voltage U_M with a small amplitude. If the equipment being tested is equipped with BB inputs (e.g. system modulators), these two signals are combined to form a signal $U_A + U_M$. The working point on the drive characteristic of the equipment being tested is determined by the instantaneous value of the sweep voltage. If the amplitude and phase response of the unit being tested depends on the working point, then amplitude and phase modulation of the test voltage will vary with the deflection frequency during sweeping of the pass band.

The receiver demodulates the modulated test voltage accordingly for amplitude and phase. The resulting voltages are a direct indication of the drive - dependent amplitude and phase distortions; they are evaluated on the built-in monitor, the recovered sweep voltage U_A being used for X-deflection.

The low test frequencies (starting at 25 kHz) make it possible to examine frequency or phase-modulated systems for very small channel numbers (4 channels or more) with the RM-5.

It has generally become accepted that measurements must also be carried out with high test frequencies (up to 5.6 MHz!) in order to detect all possible faults. Naturally, these high test frequencies are also demodulated in the receiver of the MeasuringSetup RM-5.

Distortion measurements at the IF level - particularly at high test frequencies - require high precision of the test equipment. In the case of the Radio-Link Measuring Setup RM-5, this accuracy is achieved by double modulation of the signal U_M and U_A at the generator side and tracking demodulation at the receiver side.

At high test frequencies, the sidebands of the swept IF carrier frequency can lie outside the pass band, unless suitable measures are implemented, and can thus falsify the results of measurement. The RM-5 prevents such measuring errors with the "automatic sweep reduction", which has proved its value in preceding models.

End-to-end measurements are simplified by automatic tuning of the receiver to the measuring frequency being used. Matching to the level of the received signal at the IF level or the BB level is also carried out automatically.

Display of the measured results on the monitor of the RME-5 is carried out in a completely new manner. This monitor, which operates on the video principle, permits simultaneous display of measured curves and measured values, i.e. graphic and alphanumeric results in specific zones of the screen. This means that any necessary additional information for the sweep curves can be

seen at a glance and results in an elegant and complete display of the results if the results are logged by photographing the screen or by printing the screen contents via the "monitor output". The IF level at the center frequency and the measuring deviation are displayed on the screen to ensure that the measuring conditions are maintained. The IF center frequency and the sweep width are determined by a built-in frequency counter and are displayed with the sweep curves together with the test frequency and the selected measuring mode.

A further feature which should be emphasized is the facility for displaying two sweep curves on the monitor simultaneously, not only the distortion measurement results $\Delta\tau$ or $\Delta\varphi$ and $\Delta U/U_o$ [1], but also the IF frequency responses of level and return loss. Pushbuttons permit the selection of the two results to be displayed simultaneously.

The calibrated measuring ranges for distortion parameters and frequency response measurements can be set by means of stepping pushbuttons, and the scale is displayed directly on the screen.

The microprocessor of the RME-5 offers further attractive advantages in display and evaluation of sweep curves.

Frequency markers are now displayed as a variable pair of lines which are symmetrical with respect to the IF center frequency (vertical center line). Similarly, a pair of horizontal lines can be displayed as tolerance limits for the sweep curves.

Noisy curves, such as can occur during measurements via satellites, can be detected or evaluated better by means of "noise averaging". Depending on the signal-to-noise ratio and the amount of smoothing required, five averaging factors are available.

To eliminate intrinsic distortion of the measuring setup or to permit alignment of the equipment being tested to a preset curve, a reference curve can be stored and the deviation of the actual curve from this curve is displayed.

Curve analysis is possible for all distortion measurements. The linear component (slope) and the quadratic component (parabolic component) of the curve are calculated within a freely selectable frequency interval and displayed on the screen.

In the operating mode "Bessel spectrum", the receiver displays the frequency modulated input signal in the form of a spectrum - which means that it acts as a "spectrum analyser". This operating mode is used for calibration of the r.m.s. value frequency deviation meter of the RME-5 and for adjustment of the characteristic slopes of system modulators and demodulators.

For adjustment of the IF center frequency of system modulators, a monitor display with increased resolution of the IF center frequency can be selected with the aid of the "frequency counter function" of the RME-5.

In addition to the above-mentioned facilities for monitor display, the microprocessor of the receiver permits external evaluation of the results by means of a computer which is compatible with the IEC Bus - and the RME-5 has full remote control facilities. Instead of the <IEC-625> Interface Card for remote control, which is available as an Option, an XY-Plotter Interface for logging of sweep curves can be fitted.

If a complete measuring setup is installed at each end of a link for end-to-end measurements, the sweep measurement results can be returned to the transmitting side. This has the advantage that the alignment work necessary at the transmitting side can be carried out with simultaneous observation of its results.

The Radio-Link Measuring Setup RM-5 is a modern instrument which offers a wide range of applications while remaining easy to use.

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1) See "expressions, abbreviations, and definitions"

Expressions, abbreviations, and definitions

Sweep voltage	$\hat{U}_A$	:	Also called deflection voltage, peak value of (sinusoidal) sweep voltage.
	U_A	:	Instantaneous value of the sweep voltage.
Test voltage	U_M	:	RMS value of the (sinusoidal) test voltage.
	$U(U_A)$	:	Magnitude of received test voltage as a function of U_A.
	U_o	:	Magnitude of the received test voltage at $U_A = 0$.
Linearity distortions [1)] / Differential gain [1)]	$\Delta U/U_o$	=	$\frac{U(U_A)-U_o}{U_o} \times 100\ \%$
Group delay distortion [1)]	$\Delta\tau$	=	$\tau - \tau_o$ in ns
	τ , τ_o	=	Group delay of test signal at a working point determined by U_A or $U_A = 0$.
Differential phase [1)]	$\Delta\varphi$	=	$\varphi - \varphi_o$ in % rad
	φ , φ_o	=	Phase angle of test signal at a working point determined by U_A or $U_A = 0$.
IF center frequency	F_o	:	IF carrier frequency 70 MHz (35 MHz).
Sweep width	$\Delta\hat{F}$	:	Peak value of IF sweep width caused by $\hat{U}_A$.
Sweep frequency	f_A	:	Frequency of the sweep voltage.
Test deviation	Δf	:	RMS value of a frequency deviation caused by U_M or an external sinusoidal signal.
Test frequency	f_M	:	Frequency of the test voltage.
Reduced sweep width	$\Delta\hat{F}_{RED}$	:	Automatic sweep width reduction as the test frequency is increased $\Delta\hat{F}_{RED} = \Delta\hat{F} - f_M$.
Baseband	BB	:	Name for the wideband signal (telephone multiplex or TV signal) with which the IF carrier of a radio-link or satellite system is modulated. In the RM-5, the designation "BB" is used for both inputs and outputs and subassemblies which process, generate, or modify the BB signals or other signals in the same frequency range, such as noise signals or single sinusoidal signals.
Intermediate frequency(band) IF		:	In radio-link and satellite systems, the wideband BB signal generally modulates the frequency of an IF carrier signal. The IF carrier or center frequency is 70 MHz for systems with up to 1800 channels. In the RM-5, the designation "IF" is used for inputs and outputs and for subassemblies which process, generate, or modify the frequency modulated IF signals in the specified IF band.

1) In these operating instructions, the terms "linear distortion" and "group delay distortion" are used for the frequency range up to 1 MHz. Above this (arbitrary) limit, the expressions "differential gain" and "differential phase" are used.

1 SPECIFICATIONS

1.1 COMPLETE SETUP RM-5

1.1.1 FREQUENCIES AND FREQUENCY RANGES

1.1.1.1 IF Center frequency "F_o"

Standard ..... 70 MHz
Option (switch selectable) ..... 35 MHz

1.1.1.2 IF-Band

Standard (F_o = 70 MHz) ..... 45 MHz to 95 MHz
Option (F_o = 35 MHz) ..... 25 MHz to 45 MHz

1.1.1.3 Test frequencies "f_M"

(Series I or II as alternatives, f_M < 1 MHz)
Series I ..... 27.778; 55.556; 92.593; 277.778; 555.556 kHz
Series II ..... 25; 50; 83.3; 250; 500 kHz
High test frequencies (f_M > 1 MHz) ..... 2.4 and 5.6 MHz
Alternatively (as Option) ..... 3.580; 4.430 MHz bzw. 3.579545; 4.433619 MHz

1.1.1.4 Sweep frequency "f_A" (sinusoidal)

Integral ..... 18 and 70 Hz
Two selectable alternatives, in range (Option) ..... 18 to 70 Hz
Externally applicable in range ..... 18 to 70 Hz

1.1.2 DISTORTION MEASUREMENTS IN THE IF (INTERMEDIATE FREQUENCY) BAND[1)]

Unless particular data are stipulated, the data are valid over the complete input level range, P_I, from -20 to +10 dBm and for the IF range 70 MHz (Standard) and 35 MHz (Option). The following specified measurement range values are valid for the full height of the 6 cm CRT screen graticule. These are divided into 4 divisions on the screen, each separated by 1.5 cm.

1) If not otherwise noted the specified data are valid under rated conditions of use. With test frequencies, f_M = 25 and 50 kHz or 27.778 and 55.556 kHz, the sweep frequency, f_A = 18 Hz, should be used.

1.1.2.1 Group delay distortion "$\Delta\tau$" ($f_M \leq 1$ MHz)

Measurement ranges

f_M = 500 or 555.556 kHz	0.8 to 80 ns
f_M = 250 or 277.778 kHz	1.6 to 160 ns
f_M = 83.3 or 92.593 kHz	4 to 400 ns
f_M = 50 or 55.556 kHz	8 to 800 ns
f_M = 25 or 27.778 kHz	16 to 1600 ns
Maximum sensitivity[1]	0.2 ns/Div.

Intrinsic distortion[1]:

from 58 to 82 MHz	$\leq$ 0.4 ns
from 45 to 95 MHz	$\leq$ 1.0 ns
from 30 to 40 MHz[2]	$\leq$ 0.5 ns
from 25 to 45 MHz[2]	$\leq$ 2.0 ns
Intrinsic noise [1)3)] (peak-to-peak)	$\leq$ 0.1 ns

1.1.2.2 Linearity distortion "$\Delta U/U_o$" ($f_M \leq 1$ MHz)

Measurement ranges	0.4 to 40%
Maximum sensitivity	0.1%/Div.

Intrinsic distortion:

from 58 to 82 MHz	$\leq$ 0.1%
from 45 to 95 MHz	$\leq$ 0.3%
from 30 to 40 MHz [2]	$\leq$ 0.2%
from 25 to 45 MHz [2]	$\leq$ 0.8%
Intrinsic noise [3] (peak-to-peak)	$\leq$ 0.05%

1.1.2.3 Differential phase "$\Delta\varphi$" ($f_M \geq 1$ MHz)

Measurement ranges	0.4 to 40% rad
Maximum sensitivity	0.1% rad/Div.

Intrinsic distortion:

from 58 to 82 MHz	$\leq$ 0.5% rad
from 45 to 95 MHz	$\leq$ 1.0% rad
Intrinsic noise [4] (peak-to-peak)	$\leq$ 0.05% rad

---

1) Test frequency 500 or 555.556 kHz

2) With integral 35 MHz IF (Option)

3) Averaging factor 32; r.m.s. frequency deviation $\Delta f \geq 200$ kHz

4) Averaging factor 32; r.m.s. frequency deviation Δf = 500 kHz

1.1.2.4 Differential gain "$\Delta U/U_o$" (f_M > 1 MHz)

Measurement ranges ..... 0.4 to 40%

Max. sensitivity ..... 0.1%/Div.

Intrinsic distortion

from 58 to 82 MHz ..... $\leq$ 0.2%

from 45 too95 MHz ..... $\leq$ 0.4%

Intrinsic noise [1] (peak-to-peak) ..... $\leq$ 0.05%

1.1.2.5 Attenuation frequency distortion "ΔP_I"
(IF frequency response)

Measuring ranges ..... 0.4 to 16 dB

Max. sensitivity ..... 0.1 dB/Div

Max. intrinsic distortion[2]

in range:

45 to 95 MHz (P_I = +3 dBm) ..... $\pm$0.05 dB

(P_I = -20 to +10 dBm) ..... $\pm$0.1 dB

30 to 40 MHz[3] (P_I = +3 dBm) ..... $\pm$0.15 dB

(P_I = -20 to +10 dBm) ..... $\pm$0.25 dB

25 to 45 MHz[3] (P_I = +3 dBm) ..... $\pm$0.25 dB

(P_I = -20 to +10 dBm) ..... $\pm$0.35 dB

Slope correction for ΔP_I measurement

A linear variation with frequency, e.g. caused by long test cables, can be compensated for by the slope control. The correcting value can be switched out again and so has no influence on the Measuring Setup calibration.

1.1.2.6 Attenuation frequency distortion "ΔP_{II}" (selective)

(same frequency IF signal as fed into input P_I)

Level range into input P_{II} ..... -50 to -10 dBm

Measurement ranges ..... 8, 16, 40 and 80 dB

Max. sensitivity ..... 2 dB/Div.

Max. intrinsic distortion

45 to 95 MHz ..... $\pm$0.6 dB

25 to 45 MHz[2] ..... $\pm$0.6 dB

---

1) Averaging factor 32; r.m.s. frequency deviation, Δf = 500 kHz

2) Valid in temperature range +15 to +30°C

3) With integral 35 MHz IF (Option)

1.1.2.7 IF return loss "Δp_{II}"

(using Return Loss Bridge RFZ-4 or RFZ-14, see Section 4.4)

Measurement ranges ..... 8, 16, 40 and 80 dB

Max. sensitivity ..... 2 dB/Div.

Error limits when RFZ-4 Bridge is used e.g. with BNC, TNC or
1,6/10 plugs in frequency range 45 to 95 MHz
with a_r = 20 dB ..... ±1 dB
with a_r = 30 dB ..... -2.1/+1.8 dB

1.1.2.8 "$Y_{external}$" (e.g. for RF detector signals)

Measurement ranges ..... 8 to 800 mV

Max. sensitivity ..... 2 mV/Div.

Input impedance ..... 10 kΩ

1.1.3 IF MEASUREMENT PARAMETERS

The measurement parameters appear simultaneoussly with the measuring curves displayed on the CRT screen. The upper line of lettering shows the selected measurement ranges of the displayed curves and also the test frequency, f_m.
The lower lines of lettering present the parameters under 1.1.3.1 to 1.1.3.4.

1.1.3.1 Level-"p_I"

(at center frequency, F_o)

Measurement range ..... -20 to +10 dBm

Resolution ..... 0,01 dB

Error limits (after calibration with send level of 0 dBm) ..... ±0.5 dB

1.1.3.2 Test frequency deviation "Δf" (r.m.s. value)

Measurement range ..... 15 to 500 kHz

Resolution ..... 1 kHz

(Calibration by using Bessel null method and f_M = 250 kHz or 277.778 kHz
as well as f_M = 83.3 or 92.593 kHz)

1.1.3.3 Sweep width "ΔF"

Measurement range ..... ±0.2 to 25 MHz

Resolution

0.2 to 9.99 MHz ..... 0.01 MHz

10 to 25 MHz ..... 0.1 MHz

Error limits ..... $\pm 5 \times 10^{-3}$ ±1 digit

1.1.3.4 Frequency markers "M"

(two vertical traces, symmetrical about F_o)

Setting range ..... ±0.03 bis ±25 MHz

Resolution

0.03 to 9.99 MHz ..... 0.01 MHz

10 to 25 MHz ..... 0.1 MHz

Error limits ..... $\pm 5 \times 10^{-3}$ ±1 digit

1.1.3.5 Horizontal traces "⇕"

(two traces symmetrically placed about the horizontal base line)

The separation between the variable traces ..... a numerical value on the CRT screen (calculated from the measurement scale used for forming the displayed measuring curves)

1.1.4 IF COUNTER

for unswept IF signal

Measurement range ..... 25 to 95 MHz

Resolution ..... 0.01 MHz

Error limits ..... $\pm 1 \times 10^{-4}$ ±2 kHz ±1 digit

1.1.5 BESSEL SPECTRUM

For calibrating the deviation meter (RME-5) and setting the sensitivity of modulators and demodulators

Test frequencies:

with frequency series I ..... 92.593 and 277.778 kHz

with frequency series II ..... 83.3 and 250 kHz

Carrier suppression (Bessel null position)

with 92.593 and 83.3 kHz ..... ≥ 40 dB

with 277.778 and 250 kHz ..... ≥ 50 dB

1.1.6 DISTORTION MEASUREMENTS IN THE BASEBAND (BB)

Unless no particular specification is stipulated, the data are valid over the complete input level range BB from -50 dBm to -10 dBm. The following specified measurement range values are valid for the full 6 cm height of the CRT screen graticule. These are divided into 4 divisions on the screen, each separated by 1.5 cm.

1.1.6.1 Group delay distortion "$\Delta\tau$" ($f_M \leq 1$ MHz)

Measurement ranges:

f_M = 500 or 555.556 kHz	0.8 to 80 ns
f_M = 250 or 277.778 kHz	1.6 to 160 ns
f_M = 83.3 or 92.593 kHz	4 to 400 ns
f_M = 50 or 55.556 kHz	8 to 800 ns
f_M = 25 or 27.778 kHz	16 to 1600 ns
Max. sensitivity[1]	0.2 ns/Div
Intrinsic distortion[1]	$\leq$ 0.05 ns
Intrinsic noise[1)2)] (peak-to-peak)	$\leq$ 0.1 ns

1.1.6.2 Linearity distortion "$\Delta U/U_o$" ($f_M \leq 1$ MHz)

Measurement ranges	0.4 to 40%
Max. sensitivity	0.1%/Div.
Intrinsic distortion	$\leq$ 0.02%
Intrinsic noise[2] (peak-to-peak)	$\leq$ 0.05%

1.1.6.3 Differential phase "$\Delta\varphi$" ($f_M > 1$ MHz)

Measurement ranges	0.4 to 40% rad
Max. sensitivity	0.1% rad/Div.
Intrinsic distortion	$\leq$ 0.05% rad
Intrinsic noise[2] (peak-to-peak)	$\leq$ 0.05% rad

1.1.6.4 Differential gain "$\Delta U/U_o$" ($f_M > 1$ MHz)

Measurement ranges	0.4 to 40%
Max. sensitivity	0.1%/Div.
Intrinsic distortion	$\leq$ 0.05%
Intrinsic noise[2] (peak-to-peak)	$\leq$ 0.05%

1.1.6.5 BB measurement parameters

The measurement parameters appear simultaneously with the measurement curves on the CRT screen. The upper line of lettering shows the selected measurement ranges of the presented curves as well as the test frequency, f_m. And also with BB distortion measurements the above mentioned IF measurement parameters can be superimposed on the CRT screen when the associated IF signal is fed into the P_I input and "Phase U_x out of IF" is selected.

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1) Test frequency, 500 or 555.556 kHz

2) Averaging factor 32

Horizontal traces "⇕"

(two traces symmetrically placed about the horizontal base line)

The separation between the variable horizontal traces ..... a numerical value on the CRT screen (calculation from the measurement scale used for forming the displayed measuring curves)

1.1.7 BB LEVEL

for unswept signals from 10 kHz to 8.5 MHz

Measurement range ..... -50 to -10 dBm

Resolution ..... 0.01 dB

Error limits

for sinusoidal signals ..... ±0.5 dB

for noise signals ..... ±0.8 dB

1.1.7.1 BB return loss

for unswept, sinusoidal signals from 100 kHz to 8.5 MHz in conjunction with the Return Loss Bridge RFZ-14.

Level range at BB level measurement input ..... -50 to -10 dBm

Resolution ..... 0.01 dB

The error limits conform to the directivity (D) of the measurement bridge, to the Versacon® 9 test connection, and to the value of the return loss being measured.

1.1.8 INTERNAL EVALUATION

1.1.8.1 Weighting filter bandwidth for distortion measuring results

Weighting filter switched out ..... approx. 1 to 4 kHz[1)]

Weighting filter switched in ..... 300 Hz

1.1.8.2 Noise averaging

In order that extremely noisy measuring curves might be evaluated better (e.g. when measurements are made via satellite), five averaging factors are available

Averaging factors 2, 4, 8, 16 32

1.1.8.3 Curve difference

In order that intrinsic distortion might be eliminated or that a system under test might be compared with a given curve, a reference curve can be stored, and this as well as the difference to the actual curve is thereupon displayable on the CRT screen.

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1) Dependent on selected test frequency

1.1.8.4 Curve analysis

This is applicable with all distortion measurements. The positions of three points on the curve are evaluated:
one of these points is at the intersection of the curve with the vertical center line, and the two other points are at the intersection of the curve with two frequency marker lines.

"LIN": the Y difference value of the two end points or of the intersection points is ascertained and superimposed correct to scale.

"PARAB": in the image center, the Y separation between the curve and the secant formed with "LIN." is ascertained and superimposed correct to scale.

1.1.8.5 Noise calculation device (Option, in preparation)

The intermodulation noise in the associated white noise measurement channels of the baseband is calculated from the measured values of differential distortion, $\Delta\varphi$, and of differential gain distortion, $\Delta U/U_o$, of a system under test between the IF ports of the RM-5.

1.1.9 EXTERNAL EVALUATION, IEC BUS INTERFACE

The <IEC 625> Interface (Option) allows all of the curves and measurement parameters of the RME-5 to be called-out and processed further. Besides that, tolerance masks can be superimposed on the CRT screen. And almost all of the RME-5 operating functions are controllable via the <IEC 625> Interface.

1.1.10 DOCUMENTATION

1.1.10.1 Video output

A video printer permits the documentation of all of the information on the CRT screen.
Likewise an external monitor could be used for presenting a larger display.

Frame frequency ..... 50 Hz
Number of lines (without interlaced scanning) 312
Amplitude ..... 1 V_{pp}
Impedance ..... 75 Ω

1.1.10.2 X-Y chart recorder interface (Option)

Alternative to <IEC 625> Interface. For recording the distortion curves on pre-printed forms by an X-Y chart recorder.

Presentation of the sweep curve [2] and [10] in the left and right halves of the sheet.
Dimensions of a raster zone (for a sweep curve) ..... 10 x 10 cm
Output sensitivity, switch-selectable ..... 0.1 or 0.4 V/cm
Pen lift ..... "Up-Down" level invertable on interface card

1.1.10.3 CRT screen photography

A hand-held camera (with 8.5 cm x 12 cm, inside dimensions, extension tube) allows the CRT screen to be photographed direct. Owing to the superimposed graticule lines and measurement parameter values the photographs furnish excellent evaluations.

1.2 RMS-5 GENERATOR, ADDITIONAL SPECIFICATIONS

1.2.1 IF section

1.2.1.1 IF main output

Center frequency

Standard ..... 70 MHz
Option ..... 35 MHz

Error limits (after calibration)
70 MHz IF ..... ±50 kHz
35 MHz IF ..... ±25 kHz

Frequency range

for sweep and for IF offset
70 MHz IF ..... 45 to 95 MHz
35 MHz IF ..... 22.5 to 47.5 MHz

Sweep width setting

Full range $\hat{\Delta}F$ ..... 0 to ±25 MHz
Range: $\hat{\Delta}F/10$ ..... 0 to ±2.5 MHz

Error limits of setup sweep width $\hat{\Delta}F$ ..... ±2% of f.s.d. ±0.05 $\hat{\Delta}F$

Automatic sweep reduction (switch selectable)

For sweep width $\hat{\Delta}F$ ..... $\pm f_M$ to ±25 MHz
Additional error limits of reduced sweep width $\hat{\Delta}F_{RED}$
for $\hat{\Delta}F \geq \pm 2.5$ MHz (or ±0.25 MHz at $\hat{\Delta}F/10$) ..... $\pm 0.12 \times f_M$

Test frequency deviation Δf

Setting range ..... 10 to 500 kHz
Error limits ..... ±15 kHz ±0.08 Δf

IF level

Level range ..... -50 to +10 dBm
Adjustable in steps of ..... 10 dB
Continuously adjustable from ..... 0 to -10 dB

Error limits:
of 0 dBm level ..... ±0.15 dB
for levels from -50 to +10 dBm ..... ±0.5 dB

Maximum frequency response referred to an average value

at 70 ±25 MHz and 35 ±10 MHz (+3 dBm) ..... ±0.05 dB
at 70 ±25 MHz and 35 ±10 MHz (-50 bis +10 dBm) ..... ±0.1 dB
Output impedance ..... 75 Ω
Return loss (level ≥ 0 dBm, +10 dB coarse setting) ..... ≥ 30 dB
(level < 0 dBm) ..... ≥ 34 dB
Harmonic ratio a_{k2} or a_{k3} ..... ≥ 30dB
Modulation slope for external U_A- and U_M-signals ..... 10 MHz/V

1.2.1.2 IF auxiliary output

Auxiliary output decoupled from IF main output and at same signal frequency.

Level (not A.L.C.) ..... about -6 dBm
Output impedance ..... 75 Ω

1.2.1.3 Output "IF_0"

Option, IF calibration generator

Frequency ..... 70 MHz
With optional circuit for 35 MHz ..... switch selectable between 35 and 70 MHz
Error limits ..... $\pm 5 \times 10^{-5}$

Level ..... +5 dBm
Error limits ..... ±0.5 dB
Output impedance ..... 75 Ω
Return loss ..... ≥ 30 dB
Harmonic distortion ratio a_{k2} or a_{k3} ..... ≥ 30dB

1.2.2 BB SECTION

1.2.2.1 BB output "$\hat{U}_A + U_M$"

Test frequencies, f_M

Series I ..... 27.778; 55.556; 92.593; 277.778; 555.556 kHz
As alternative
Series II ..... 25; 50; 83.3; 250; 500 kHz

High test frequencies ..... 2.4 and 5.6 MHz
As alternative ..... 3.580; 4.430; 3.579545; 4.433619 MHz

Error limits ..... $\pm 2 \times 10^{-5}$

Test voltage, U_M (r.m.s. value), setting ranges

Setting ranges: linear scale ..... 10 to 500 mV
logarithmic scale ..... -15 to +5 dBm
Error limits of U_M setting ..... ±15 mV ±0.03 U_M
Additional switch-selectable attenuation ..... 2 x 20 dB
Error limits of each attenuator stage ..... ±0.2 dB

Sweep voltage $\hat{U}_A$

Sweep frequencies, Δf_A ..... 18 and 70 Hz
Error limits ..... $\pm$2%

Setting range of sweep voltage, $\hat{U}_A$ ..... $\pm$0,05 to $\pm$2,5 V
Error limits ..... $\pm$25 mV $\pm$0.03 $\hat{U}_A$
Additional adjustable attenuation ..... 20 dB

Automatic reduction of sweep voltage (switch-selectable) by
the setting of the appropriate sweep width, $\Delta\hat{F}$ ..... $\pm f_M$ to $\pm$25 MHz
Additional error limits of the reduced sweep voltage ..... $+0.12 \times f_M \times \hat{U}_A/\Delta\hat{F}$

Output impedance ..... 75 Ω

Return loss at the f_A and f_M frequencies ..... $\geq$ 30 dB

Harmonic distortion ratio a_{K2} or a_{K3} ..... $\geq$ 30 dB

1.2.2.2 Input "U_M external" (back panel)

For external test frequencies, f_M ..... 25 kHz to 5.6 MHz
Input impedance ..... 75 Ω

1.2.2.3 Input "$\hat{U}_A$ external" (back panel)

For external sweep frequencies, f_A ..... 18 to 70 Hz
Input impedance ..... 75 Ω

1.2.3 AUXILIARY CONNECTORS

1.2.3.1 Counter connection (back panel)

Output frequency ZF/100
Voltage ..... TTL level
Tolerable load ..... 10 kΩ//100 pF

1.2.3.2 Remote control connector (back panel)

Selection of test frequency ..... 1 out 7
Control signals ..... TTL level
Connector ..... 14pin Amphenol connector

1.3 RME-5 RECEIVER, ADDITIONAL SPECIFICATIONS

1.3.1 IF section

1.3.1.1 IF input "P_I"

Capture and lock range "AFC"

in the 70 MHz band ..... 45 to 95 MHz
With the 35 MHz Option:
  Capture range ..... 30 to 40 MHz
  Lock range ..... 25 to 45 MHz

Least sweep width ΔF for generation of the X deflection voltage ..... $\pm$200 kHz

Level range P_I .....-20 to 10 dBm

Automatic selection of correct partial range (can be switched off).
Exceeding of range is signalled by LED.

Input impedance ..... 75 Ω
Return loss ..... $\geq$ 26 dB

Test frequency detection ..... automatic

(See 1.3.2.1 for frequencies)

Range of required test frequency deviation Δf ..... 15 to 500 kHz

IF distortion measurements

See section 1.1.2 for measuring ranges and intrinsic distortion

Error limits of display (without intrinsic distortion)
  for modes $\Delta\tau$, $\Delta\varphi$, and $\Delta U/U_o$ ..... $\pm$10% of reading
  for mode ΔP_I ..... $\pm$5% of reading

Slope correction with ΔP_I (can be switched off) ..... to about $\pm$0.02 dB/MHz
Correction range "Phase U_x" ..... $\pm$6°

1.3.1.2 IF input "P_{II}"

Mode ΔP_{II} (selective)

Frequency range ..... as with IF input P_I (1.3.1.1)

X deflection through IF reference signal at same frequency, applied to IF input P_I

Level range ..... -50 to -10 dBm

Error limits of displayed level difference ΔP_{II} at frequency F_o
referred to the -30 dBm input signal ..... $\pm$0.5 dB $\pm$5% of reading

Maximum frequency response referred to an average value ..... $\pm$0.4 dB

Input impedance ..... 75 Ω

Return loss ..... $\geq$ 26 dB

1.3.2 BB section

1.3.2.1 Input, "BB" ($\hat{U}_A$ + U_M)

Test frequencies, f_M

Series I ..... 27.778; 55.556; 92.593; 277.778; 555.556 kHz
As alternative
Series II ..... 25; 50; 83.3; 250; 500 kHz
High test frequencies ..... 2.4 and 5.6 MHz
As alternative ..... 3.580; 4.430; 3.579545; 4.433619 MHz

Detection of correct test frequency ..... automatic

Capture range ..... $\pm 2 \times 10^{-5}$

Level range for U_M ..... -50 to -10 dBm

Selection of correct partial range ..... automatic

LED signals the exceeding of a range.

Sweep frequency, f_A ..... sinusoidal

Automatic synchronization in range, 18 to 70 Hz

Sweep voltage, $\hat{U}_A$ in range ..... $\pm$50 mV to $\pm$5 V

"Phase U_x" setting range ..... 0 to 360°
Input impedance ..... 75 Ω
Return loss for f_M ..... $\geq$ 26 dB

BB Distortion measurement

For measurement ranges and intrinsic distortion see Section 1.1.6
Error limits of display (without intrinsic distortion)
for the modes: $\Delta\tau$, $\Delta\varphi$, $\Delta U/U_o$ ..... $\pm$10% of measured value

1.3.2.2 Input "BB level"

For frequency and measurement ranges see Section 1.1.7
Input impedance ..... 75 Ω
Return loss ..... $\geq$ 26 dB

1.3.2.3 Input, "$Y_{external}$" (back panel)

Input, for example for RF detector signals
See para. 1.1.2.8 for specifications

1.3.2.4 Demodulator output (back panel)

Output for the demodulated U_M test signal

Demodulator sensitivity
in rated range of ambient temperature ..... 60 mV/MHz ±10%
Output impedance ..... 75 Ω

1.3.3 PRESENTATION OF MEASURED RESULTS

The video technique used with the CRT permits the display of all results and measurement parameters - both in the graphic as well as in the alphanumeric forms.

1.3.3.1 Graphic presentation

Simultaneous presentation of the CRT screen graticule and two measuring curves; any combination of the modes:

$\Delta\tau$, $\Delta\varphi$, $\Delta U/U_o$, ΔP_I, ΔP_{II} and Y_{ext}

Vertical offset of the two measuring curves, independent from one another, over the whole range of the CRT screen graticule

Size of CRT screen graticule ..... 6 cm x 8.4 cm
corresponding to ..... 205 lines x 256 pixels

Configuration of CRT screen graticule
horizontal ..... 5 lines
vertical ..... 3 lines
in addition, two variable frequency marker traces

Instead of the two measuring curves displayed on the CRT screen, two variable horizontal traces can be displayed symmetrical about the center trace.

With simultaneous display of two distortion measurement results, arrows indicate the associated curves at the relevant mode.

When a spectrum is displayed, the only lines presented are the boundries of the CRT screen graticule.

1.3.3.2 Alphanumeric presentation

Three lines, above and below the CRT screen graticule, provide alphanumeric characters for presentation of the measurement parameters: measurement ranges, test frequency, sweep width, center frequency, marker separation, IF amplitude level and test deviation.

In conjunction with the evaluation of measuring curves more parameters can appear within the CRT screen graticule: i.e. results of curve analyses, "LIN.", "PARAB".

1.4 O P T I O N S

1.4.1 INTERFACE <IEC 625>

For remote control of the RME-5's functions; for transfer of measuring data, and for superimposing commenting text onto CRT screen.
See Section 1.1.9.

Adaptor plug S 834 connects to the IEEE 488 Bus.

1.4.2 X-Y RECORDER INTERFACE

for clean charting of the measuring curves by means of an X-Y recorder. See para. 1.1.10.2.

1.4.3 35 MHz IF

Incorporated in Generator and Receiver

1.4.4 IF CALIBRATION GENERATOR (Quiet Tone)

Incorporated in the RMS-5 Generator; see para. 1.2.1.3.

1.4.5 COLOR SUB-CARRIER FREQUENCIES

As alternatives to the high test frequencies 2.4 and 5.6 MHz.

Frequencies selectable as ..... 3.580 or 3.579545 MHz (M/NTSC)[1)]

and ..... 4.430 or 4.433619 MHz (B, G, H, I, PAL)[1)]

1.5 UNATTACHED ACCESSORIES

At extra cost

1.5.1 IF RETURN LOSS MEASURING BRIDGE RFZ-4

See para. 1.1.2.7

Frequency range ..... 10 MHz to 200 MHz

Characteristic impedance ..... 75 Ω

Insertion loss ..... 6.5 dB nominal

Max. measurement error, error limits ..... $0.03 \pm 0.12\ r^2$

Connector ..... Versacon® 9 basic connector with BNC adaptor

1.5.2 BB RETURN LOSS MEASURING BRIDGE RFZ-14

Frequency range ..... 100 kHz bis 100 MHz

Characteristic impedance ..... 75 Ω

Insertion loss with open circuit Z_x connector ..... 80 dB max.

Max. measurement error ..... $0.015 \pm 0.13\ r^2$

Connector ..... Versacon® 9 basic connector with BNC adaptor

1.5.3 FREQUENCY SPLITTER RMSF-4

Frequency range of $\hat{U}_A$ deflection voltage ..... 18 Hz to 100 Hz

Frequency range of U_M test voltage ..... 25 kHz to 12 MHz

Characteristic impedance ..... 75 Ω

Return loss in the relevant tolerable

frequency ranges for $\hat{U}_A$ and U_M ..... $\geq$ 30dB

---

1) The letters for "NTSC" or "PAL" designate the systems. The correlation between systems and countries is shown in Annex I, CCIR-Report 624 (Geneva 1974).

Attenuation curves

	f (kHz)	a (dB)
of the low-pass filter	≤ 0.1	≤ 0,3
	≥ 25	≥ 46
of the high-pass filter	≥ 25	≤ 0,25
	≤ 0,1	≥ 50

1.6 GENERAL SPECIFICATIONS

1.6.1 AMBIENT TEMPERATURE

Rated range of use (≙ limits range of operation)

Height of site of operations — Without ventilator

up to 1000 m above sea level ..... 0 to +40°C
up to 3000 m above sea level ..... 0 to +30°C

With ventilator (Option)

up to 1000 m above sea level ..... 0 to +50°C
up to 3000 m above sea level ..... 0 to +40°C

Storage and transport ..... -40 to +70°C

1.6.2 POWER SUPPLY

Mains voltage ranges:
- Generator RMS-5 ..... 96.5 to 140 V and 193 to 261 V
- Receiver RME-5 ..... 96.5 to 261 V

Mains frequency range ..... 47.5 to 63 Hz

Safety class to IEC 348 and VDE 0411 I

EMI/RFI suppression corresponds to VDE 0871

Power consumption of:
- RMS-5 Generator ..... approx. 50 VA
- RME-5 Receiver ..... approx. 80 W

1.6.3 DIMENSIONS (in mm)

RMS-5 Generator

Bench model

Width with handles 477
Height overall 155
Depth with handles 434

19" Rack mounting (DIN 41 494)

Width 443
Height (6 units) 264
Depth 379

19" conversion kit ..... BN 700/00.03

RME-5 Receiver

Bench model

Width with handles 477
Height overall 288
Depth with handles 434

19" Rack mounting (DIN 41 494)

Width 443
Height (3 units) 264
Depth 379

19" conversion kit ..... BN 700/00.06

1.6.4 WEIGHT

RMS-5 Generator ..... approx. 13 kg

RME-5 Receiver ..... approx. 19.5 kg
with Ventilator Attachment ..... approx. 20.5 kg

1.7 ORDERING INFORMATION

Radio-Link Measuring Setup RM-5

Basic version for 70 MHz IF, with test frequencies Series I: 27.778; 55.556; 92.593; 277.778; 555.556 kHz and two higher test frequencies (for selection, see under Options):
Sweep frequencies 18 and 70 Hz
Comprising RMS-5 Generator* BN 916/01
and RME-5 Receiver* BN 917/01

Radio-Link Measuring Setup RM-5

Basic version for 70 MHz, with test frequencies Series II: 25, 50, 83.3, 250, 500 kHz and two higher test frequencies (for selection, see under Options):
Sweep frequencies 18 and 70 Hz
Comprising RMS-5 Generator BN 916/02
and RME-5 Receiver BN 917/02

* Equipped with the 75 Ω basic connector Versacon® 9 and BNC adapter. For other adapter types, see "Specification Sheet Versacon® 9, and order chosen type when ordering instrument.

Options for permanent incorporation:[1]

	Incorporation in RMS-5	Incorporation in RME-5
Higher test frequencies[2]		
(two frequencies are incorporable)		
Color sub-carrier		
M/NTSC 3.579545 MHz, instead of 2.4 MHz	BN 916/00.04	BN 917/00.04
B, G, H, I/PAL 4.433619 MHz, instead of 5.6 MHz	BN 916/00.05	BN 917/00.05
M/NTSC 3.580 MHz, instead of 2.4 MHz	BN 916/00.06	BN 917/00.06
B, G, H, I/PAL 4.430 MHz, instead of 5.6 MHz	BN 916/00.07	BN 917/00.07
Measuring frequency		
2.4 MHz (without extra cost)	BN 916/00.08	BN 917/00.08
5.6 MHz (without extra cost)	BN 916/00.09	BN 917/00.09
Interface <IEC 625>		
with adaptor plug IEC 625/IEEE 488 (S 834)	-	BN 853/07
X-Y chart recorder interface[3]	-	BN 917/00.01
IF calibration generator*	BN 916/00.02	-
35 MHz extension	BN 916/00.03	BN 917/00.03
Noise calculation device	-	in preparation

Unattached Accessories (at extra cost):

Ventilator Attachment for RME-5	BN 917/00.10
IF Return Loss Measuring Bridge RFZ-4*	BN 697/00.04
BB/IF Return Loss Measuring Bridge RFZ-14*	BN 830/00.01
Frequency $\hat{U}_A$, U_M; splitter RMSF-4*	BN 696/00.08
X-Y chart forms, 50 sheets, German	BN 6390/00.14
X-Y chart forms, 50 sheets, Englisch	BN 6390/00.21
Transport Case TPK-3 for RMS-5 Generator	BN 626/09
Transport Case TPK-6 for RME-5 Receiver	BN 626/12
Transportation Protection Covers (1 set for front and back panels)	
SD-3 for RMS-5 Generator	BN 700/00.23
SD-6 for RME-5 Receiver	BN 700/00.26

1) Unless otherwise stated, the Device is incorporated at the factory at an extra cost

2) The RM-5 Measuring Setup is delivered with 2.4 and 5.6 MHz test frequencies if no request is made for the high test frequencies with order.

3) Alternative to Interface Bus <IEC 625>, for incorporation

4) At extra cost

* Equipped with the 75 Ω basic connector Versacon®9 and BNC adapter. For other adapter types, see "Specification Sheet Versacon ®9, and order chosen type when ordering instrument.

2 TECHNICAL DETAILS

This section describes the basic principle of operation of the RM-5 on the basis of simplified block diagrams.

First, the method of distortion measurements used in the RM-5, which was mentioned briefly in the "Introduction", is presented again, before dealing with details of the circuits in the generator and receiver.

2.1 PRINCIPLE OF DISTORTION MEASUREMENTS IN THE RM-5

Figure 2-1 shows the intermodulation principle used for determining amplitude and phase distortions on an IF-(RF)-IF link.

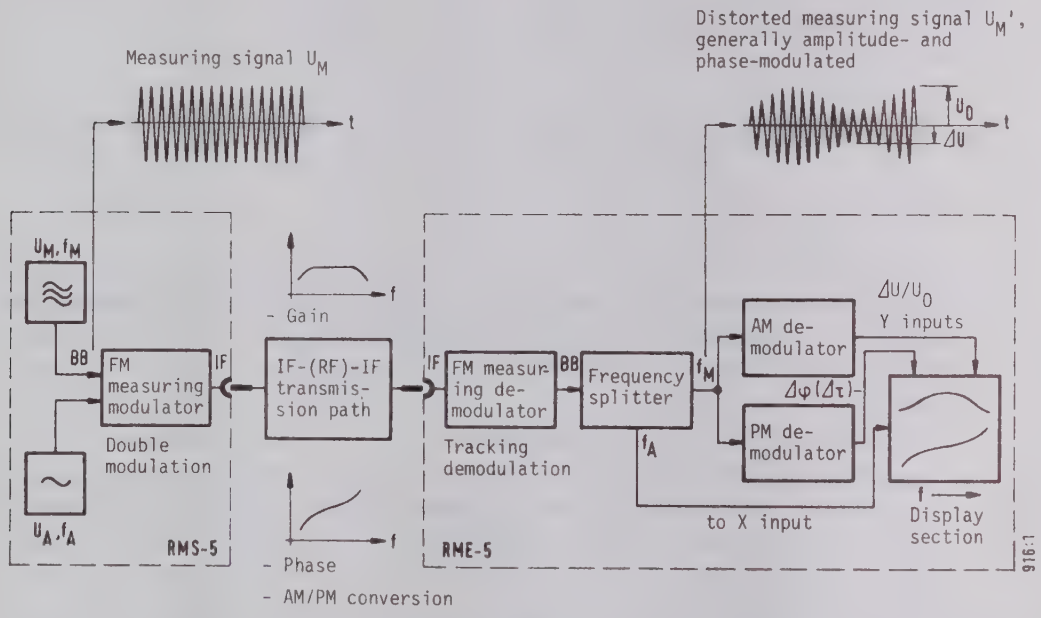


Figure 2-1 Measuring principle for detecting amplitude distortions $\Delta U/U_0$ and phase distortions $\Delta\varphi$

In the generator, the test modulator receives the low frequency sweep voltage U_A (f_A = 18 Hz or 70 Hz) and the high frequency test voltage U_M, which represents a signal from the baseband of an FM radio-link system. The amplitude of the sweep voltage is considerably larger than that of the test voltage.

The output of the FM modulator delivers a carrier, which is frequency-modulated by the test voltage and whose center frequency F_0 sweeps slowly over the whole band-width of the IF-(RF)-IF link at a rate determined by the frequency f_A (see Figure 2-2a). The modulation index η is - at least at the higher test frequencies - considerably less than 1 due to the low amplitude of the test voltage U_M. The frequency spectrum (Bessel spectrum) at the modulator output then consists only of the carrier U_T and the first side lines U_{M1}, U_{M2}. This frequency triplet scans the IF-(RF)-IF band-width. A vector diagram of the frequency triplet is shown in Figure 2-2b.

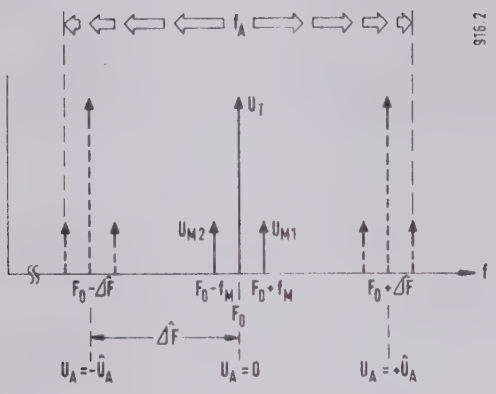
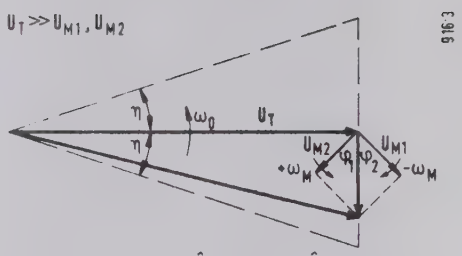


Figure 2-2a Swept frequency triplet of the FM signal



$\omega_0 = 2\pi f_0$. $F_0 - \hat{\Delta F} \leq f_0 \leq F_0 + \hat{\Delta F}$

$\omega_M = 2\pi f_M$. Sweep range

Figure 2-2b Vector diagram of the frequency triplet ($\eta \ll 1$, not shown to scale)

If the attenuation of the IF-IF link is dependent on the frequency, the length of the vector U_T, U_{M1}, U_{M2} is dependent on the instantaneous value of the frequency ω_0. The proportions of the vector diagram change periodically with the sweep frequency. It can be shown that this has the effect of amplitude modulation on the test signal U_M (t) if subsequent limiting is ideal[1].

The output signal of the FM test demodulator consists of the sweep signal superimposed with the distorted test signal. The sweep signal is connected to the X-input of the video section, while the test signal is connected to the amplitude demodulator, whose output voltage is proportional to the amplitude variation ΔU. ΔU referred to the value U_0 is displayed via the Y-input of the video section (see Figure 2-1, test signal U'_M (t)). U_0 is the value of U_M at $\hat{\Delta F} = 0$ or $\hat{U}_A = 0$.

If the phase of the signal varies with the frequency, the vectors U_M, U_{M2} no longer rotate at the constant angular velocity ω_M when the phase curve is sampled. As a result of this, a signal phase modulated with the frequency f_A appears at the output of the test demodulator. The distorted test signal is compared in a phase demodulator with a constant phase sinusoidal voltage. The output voltage, proportional to the phase deviation $\Delta\varphi$, of the value at $\hat{\Delta F} = 0$ or $\hat{U}_A = 0$ is connected to the second Y-input and displayed.

The measured parameters $\Delta U/U_0$ and $\Delta\varphi$ are called "differential gain" and "differential phase", and can be displayed simultaneously in a freely selectable frequency interval $2\hat{\Delta F}$ on the screen ($\hat{\Delta F}$: sweep width).

If a low test frequency (f_M < 1 MHz) is selected, then the width 2 f_M of the frequency triplet is so narrow that the section of the phase curve in the range $f_0 - f_M$ to $f_0 + f_M$ can be regarded as linear. In this case, $\Delta\varphi$ is a dimension for the rate of change of the phase curve and thus an indication for the change of the "group delay $\Delta\tau$".

In the case of amplitude variations at low test frequencies, the distortion is called "linear distortion $\Delta U/U_0$".

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1) R.Dick: Detection of errors in the transmission path of FM signals with the aid of modern distortion measuring equipment, Order No. 5022

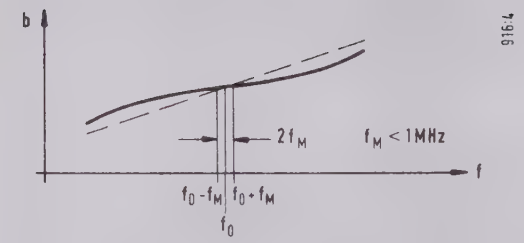

Figure 2-3 Phase curve of the IF-IF link

An advantage of this measuring method is, in addition to detection of frequency-dependent attenuation and group delays, the possibility of detecting interference caused by AM/PM conversion. The cause of the interference can be determined from the shape of the result and its dependency on the test frequency f_M [1] (see also Section 4.1.2).

For more information on the basic principles, see the pamphlet "Distortion measuring techniques on radio-link systems" by H. Gommlich, published by W&G, Order No. 6134.

2.2 PRINCIPLE OF OPERATION OF THE GENERATOR RMS-5

Figure 2-4 shows a simplified block diagram of the generator with the most important subassemblies for BB and IF signal generation. Particular emphasis is placed on the principle of operation of the double modulation. The main advantage of this method is the extremely low distortion generated during frequency modulation.

2.2.1 BB SIGNAL GENERATION

Sweep signal U_A, f_A

Two sinusoidal voltages with frequencies f_A = 18 Hz or f_A = 70 Hz are available as sweep signals. It is possible to set the amplitude $\hat{U}_A$, which determines the sweep width $\hat{\Delta F}$, via a potentiometer which is calibrated in Volts (BB measurements) or, if the internal measuring modulator is used, to set the sweep width directly in MHz via a second potentiometer (IF measurements).

Test signal U_M, f_M

Seven fixed values in the range 25 kHz to 5.6 MHz can be selected as test frequencies. Instead of the 2 high test frequencies (2.4 and 5.6 MHz), 2 optional color carrier frequencies can be used. The fixed frequencies are obtained from crystal controlled oscillators in the test signal generation circuit. The RMS value of the test voltage U_M, which determines the "r.m.s. value frequency deviation Δf", is set by means of a potentiometer with a kHz scale if the internal test modulator is used or with a dBm scale for measurement with external modulators. The test voltage can be reduced by 20 dB (20 dB pushbutton).

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1) R.Dick: Detection of errors in the transmission path of FM signals with the aid of modern distortion measuring equipment, Order No. 5022

Adder stage for the BB signal

The test and sweep voltages are connected via an adder stage to the BB output socket $\hat{U}_A$ + U_M. This sum voltage can be reduced by 20 dB (20 dB pushbutton), permitting sufficiently fine adjustment of the voltages for modulators with steep slopes.

2.2.2 AUTOMATIC SWEEP REDUCTION

If the automatic exploring range function is active, the sweep voltage is automatically reduced when the generator is set to a high test frequency such that the sideband frequencies of the IF do not exceed the preselected sweep range limits. If a test frequency which is higher than the preselected sweep width $\Delta\hat{F}$ is selected, the sweep signal is switched off. This condition is signalled by an indicator lamp.

2.2.3 IF SIGNAL GENERATION, DOUBLE MODULATION

The test signal and the sweep signal are connected parallel within the unit to the frequency modulator. As shown in Figure 2-4, the IF carrier signal in the RMS-5 is generated by mixing two high frequencies. The equation for the frequencies supplied by oscillators I and II is:

830 MHz - 760 MHz = 70 MHz

795 MHz - 760 MHz = 35 MHz (35 MHz IF available as Option)

As both oscillators are modulated (but with different frequencies), the principle is called double modulation: The sinusoidal test voltage U_M (with the frequencies 25 kHz ... 5.6 MHz) generates frequency modulation in oscillator I. Due to the relatively low test voltage, a small frequency deviation Δf results, which means that the working point varies only slightly over the voltage - frequency characteristic. The distortion resulting from oscillator I is therefore negligible.

The frequency of oscillator II is swept with the low frequency sweep voltage (18/70 Hz) over the range 830 $\pm$ 25 MHz or 795 $\pm$ 10 MHz, depending on the selected IF. Combination of these two oscillator signals in the mixer results in a frequency-modulated and simultaneously swept IF signal of high linearity.

Despite the great drive signal, the frequency deviation $\Delta\hat{F}$ is proportional to the deflection or sweep voltage U_A at any instant: In the frequency control circuit, the actual value supplied by a strictly linear frequency discriminator is compared with the setpoint, i.e. the instantaneous value of the sweep signal. Any difference between the actual value and the setpoint generates a voltage with which the frequency of oscillator II is corrected.

The IF center frequency F_o can be checked and calibrated via a comparator circuit with LED indication. In addition, offsetting of the center frequency F_o by up to $\pm$25 MHz ($\pm$12.5 MHz) can be achieved by varying the center frequency of oscillator II.

IF output signal

The low-pass filter following the mixer suppresses unwanted mixing products which result from conversion of the two oscillator signals. There are two IF outputs. At one IF output, the level can be adjusted continuously between -50 and +10 dBm, while the second IF output delivers a fixed level of -6 dBm.

IF calibration generator (Option)

The IF calibration generator delivers a 70 or 35 MHz signal with high frequency accuracy and very low noise and harmonic content at the output IF_o. This is intended for "quiet tone" measurements. The level at output IF_o is +5 dBm.

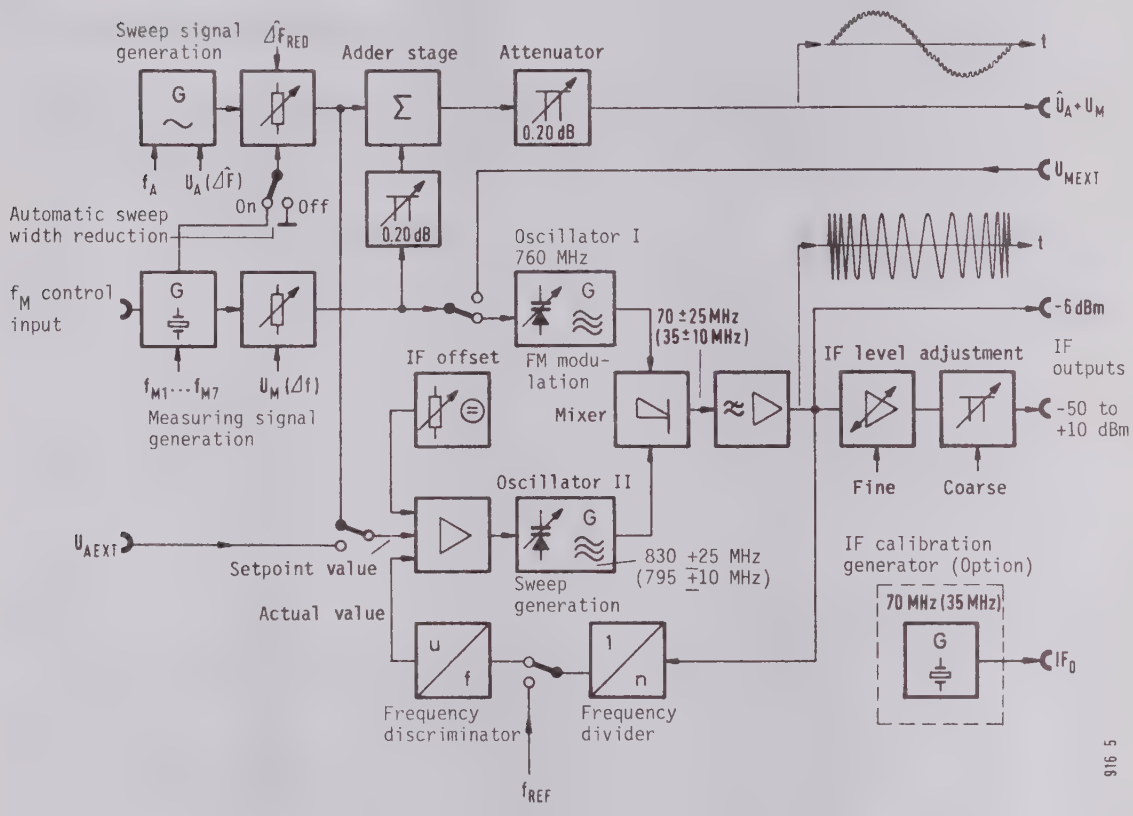


Figure 2-4 Simplified block diagram of the RMS-5 Generator

2.3 PRINCIPLE OF OPERATION OF THE RECEIVER RME-5

2.3.1 BLOCK DIAGRAM OF THE RME-5

Figure 2-5 shows the block diagram of the receiver with the three main groups:

- IF section
- BB section with "Digital X-Generator"
- Digital section with microprocessor and screen control.

The tasks of the various groups and the relationships between the various functional blocks are described in the following sections.

2.3.2 IF SECTION

2.3.2.1 IF level meter

Absolute level P_I (F_o)

The swept IF signal via the automatic input attenuator is connected to the IF level meter where the signal is rectified.

The IF level, which varies over the sweep range according to the amplitude response of the IF link, is connected through to the 12 bit A/D converter in the sampling circuit each time it passes through the frequency F_o. This is controlled at the correct point by the "Digital X-Generator".

The wide range of the 12 bit A/D converter, which converts the static result (P_{Io}, Δf, P_{BB}), permits a high resolution of the level value.

IF Distortion measurement ΔP_I

The frequency response of the IF link can be displayed in the operating mode ΔP_I.

$\Delta P_I = \Delta P_I(f)$, where $F_o - \hat{\Delta F} \leq f \leq F_o + \hat{\Delta F}$ (sweep range).

The signal ΔP_I coming from the IF level meter is connected via the selector to the 8 bit A/D converter, which converts the dynamic results.

2.3.2.2 IF distortion measurement (selective) ΔP_{II}

The RME-5 offers the facility of selective measurement of IF frequency responses with large attenuation differences, via the input P_{II}. $\Delta P_{II} = \Delta P_{II}$ (f), (f = sweep range). This also permits return loss measurements. The circuit consists mainly of the mixer at input P_{II}, with logarithmizer and rectifier. The carrier signal for the mixer is provided by the tracking oscillator, see Figure 2-6. A swept IF signal with a constant level (reference parameter) must be present at input P_I. In most cases, connection from the -6 dBm output of the RMS-5 to the receiver input P_I is used. Alternatively, a parallel, decoupled IF output of the measured system could be used.

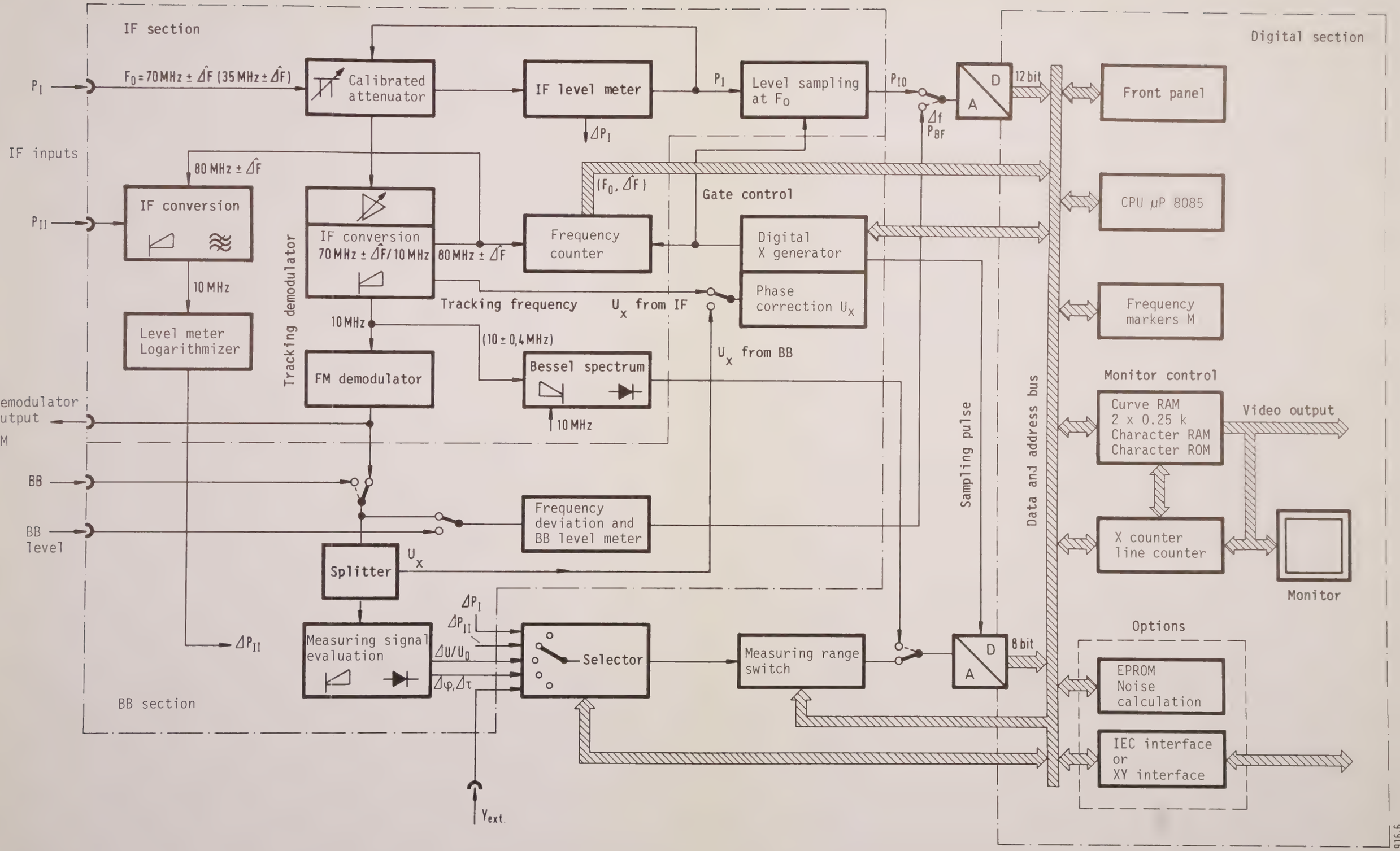


Figure 2-5 Simplified block diagram of RME-5 Receiver

2.3.2.3 Tracking demodulation

The test demodulator in the RME-5 operates on the "tracking principle" (Figure 2-6), which guarantees low distortion demodulation of the frequency-modulated IF signal. With the aid of a frequency control circuit (which is described later), the IF carrier frequency at the FM demodulator input is kept constant. In this manner, the demodulation characteristic is used only around the center frequency, which means that "frequency demodulation" is carried out in a strictly linear range.

The principle of operation of the frequency control circuit is as follows: First (as shown in Figure 2-6), the swept and frequency-modulated input signal - whose center frequency can be 70 MHz or 35 MHz - is converted in the mixer to a constant difference frequency

$f_D = f_F - f_o = 10$ MHz.

For this purpose, the mixer receives a signal with the frequency f_F from the tracking oscillator. For a 70 MHz input signal, $f_F = 80$ MHz, and this frequency can vary by up to ± 25 MHz (depending on the sweep width $\hat{\Delta F}$ of the input signal). For the 35 MHz IF, $f_F = 45 \pm 10$ MHz.

The $\pm \hat{\Delta F}$ frequency variation in the tracking oscillator is provided by a control circuit. For this purpose, the difference frequency $f_D = 10$ MHz is connected via the frequency divider to the frequency discriminator and the actual value of the output voltage is compared with the constant setpoint. This results in a low frequency, sinusoidal control voltage, which corresponds to the sweep voltage and which modifies the tracking frequency f_F such that the difference frequency remains constant at $f_D = 10$ MHz. The low frequency control voltage also supplies the deflection voltage U_x for the display section.

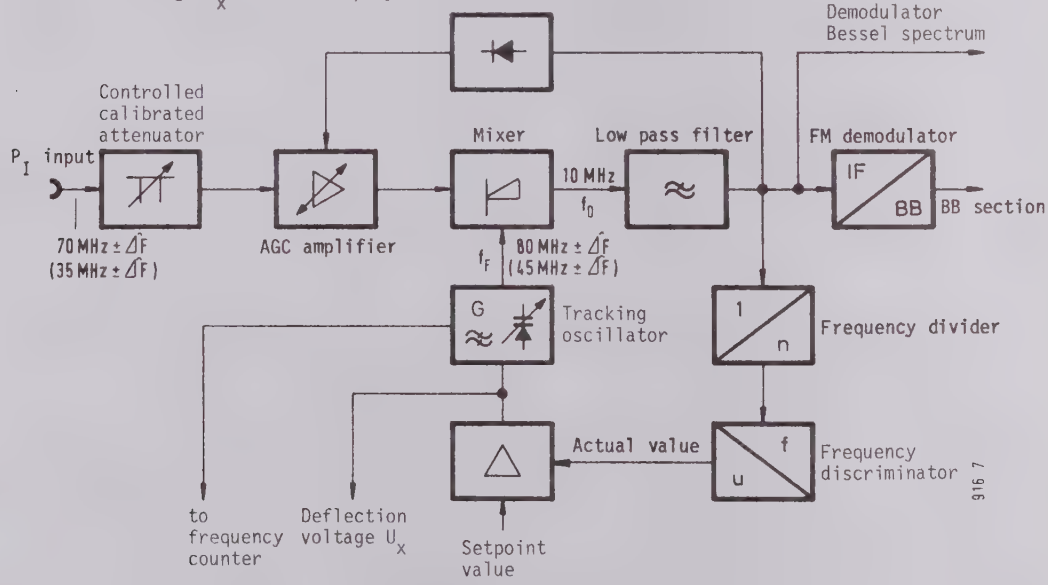


Figure 2-6 Principle of tracking demodulation in the RME-5

2.3.2.4 Bessel spectrum

For display of the FM spectrum, the tracking oscillator (see Figure 2-6) is swept such that the 10 MHz intermediate frequency, and thus the converted FM spectrum, varies by ± 0.4 MHz. This intermediate frequency is connected to the mixer of the evaluation circuit, which simultaneously receives a constant 10 MHz signal as the carrier frequency. In this operating mode, the RME-5 operates as a spectrum analyzer.

2.3.2.5 Frequency counter F_0, $\hat{\Delta}F$

The frequency counter first determines the sweep limits of the tracking frequency (80 MHz $\pm \hat{\Delta}F$) from the signal of the tracking oscillator. At the instant where the sweep voltage reaches its extreme values ($-\hat{U}_A$ and $+\hat{U}_A$), the frequency counter receives an interrogation pulse from the X-generator via the gate control. The two counter values are evaluated in the digital section, i.e. the parameter F_0 is calculated from $F_0 \pm \hat{\Delta}F$.

2.3.3 BB SECTION

2.3.3.1 Test signal evaluation

The frequency-demodulated signal which is present at the BB input (see Figure 2-7) consists of the sweep voltage and the superimposed test voltage, which is generally amplitude- and phase-modulated.

The test frequency detection circuit automatically determines the test frequency being used. Selection of the correct test frequency is carried out with the aid of band- pass filters.

Linear distortion or differential gain

Before the actual measurement, the test signal is kept constant in an AGC circuit. The amplitude modulation is not suppressed, as the AGC process is very slow. The resulting constant voltage U_0 (U_M at $U_A = 0$) acts as a reference parameter. The variation ΔU of the envelope is the measure for linear distortion or differential gain.

Group delay or differential phase

The group delay distortion $\Delta\tau$ and the differential phase $\Delta\varphi$ are determined by the phase demodulator. As measurement of group delay distortion is equivalent to a phase measurement, measuring the phase variation which results from sweeping the signal is sufficient.

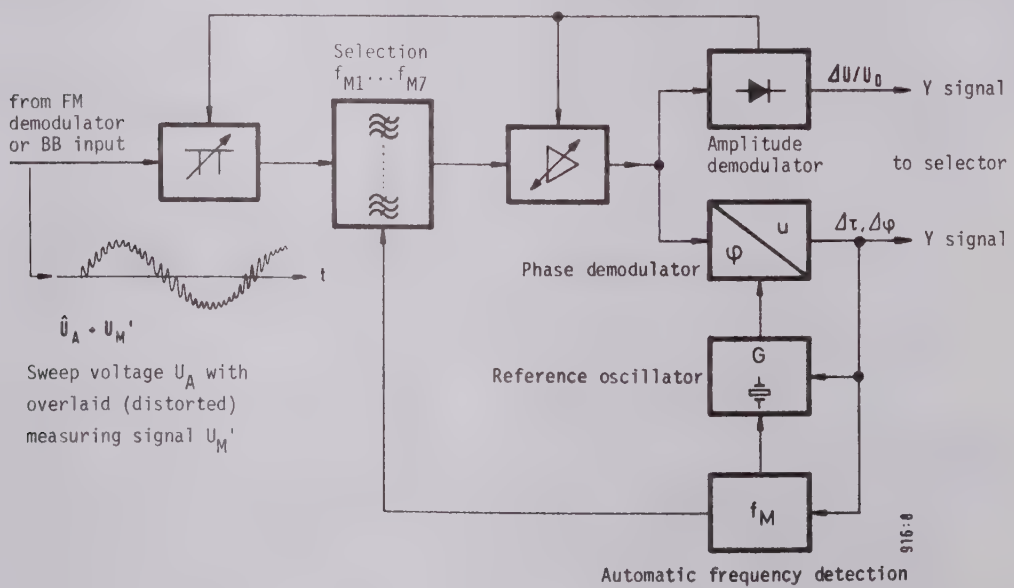


Figure 2-7 Obtaining the distortion results $\Delta U/U_0$, $\Delta\tau$, and $\Delta\varphi$ from the BB signal $U_A + U_M'$; simplified block diagram

The phase measurement result is achieved by comparison with a reference signal whose phase is constant. This signal is supplied by the crystal-controlled reference oscillator.

The output voltage of the phase meter is proportional to the phase variation, varying in the rhythm of the sweep operation.

2.3.3.2 Frequency deviation and BB level meter

The RMS value of the frequency deviation Δf is determined in the deviation measuring detector by the level of the demodulated IF signal, i.e. by U_M'. The test signal level is measured with high resolution via the 12 bit A/D converter and displayed, or combined with the value for the slope of the FM Demodulator to determine the r.m.s. value frequency deviation.

2.3.4 MICROPROCESSOR CONTROL

The microprocessor circuit consists of the central processing unit (CPU) - a microprocessor type 8085 - the monitor control with the memories for the two sweep curves and alphanumeric characters, the frequency marker generation circuit, and the input and output ports.

The controls on the front panel are connected to the microprocessor via control lines. The microprocessor accepts the commands from the keyboard and passes them on to the appropriate subassembly, initiates storage and monitor display of distortion measurement results, accepts the static measurement results, and enables them for monitor display when ordered to do so.

In addition to its pure control tasks, the microprocessor must handle mathematical tasks such as calculation of sweep limits or for evaluation of distortion curves (e.g. curve difference).

The <IEC 625> bus board, which can be fitted as an option, can handle all keyboard functions, which means that the RME-5 can be used under computer control in automatic measuring systems of modern design.

2.3.5 DIGITALIZATION OF THE SWEEP CURVES

The resolution accuracy of the analog measured results $\Delta\tau$, $\Delta\varphi$; $\Delta U/U_o$; ΔP_I; ΔP_{II}; Y_{EXT} (y direction) and of the deflection voltage U_x during digitalization is determined via the 8-bit A-D converter system. 256 steps (= 2^8 values) can be obtained, but only 205 amplitude values are displayed on the CRT screen.

The balance of the 51 amplitude values or CRT screen lines are reserved for the displaying of the alphanumeric character above and below the graphic section.
The "Digital X-Generator" converts the deflection voltage U_x into 256 voltage values during half the sweep period (frequency rise: $F_o - \hat{\Delta F}$ to $F_o + \hat{\Delta F}$) - digitalization of the frequency axis. One x address (0 ... 255) is allocated to each digital frequency value. The digital sweep operation is executed by cyclically calling-up the address sequence 0 to 255 with the aid of the X-counter in the monitor control.

Digitalization of the y signal is carried out by microprocessor control of the X generator. The microprocessor initiates analog/digital conversion whenever the x addresses coincide. Correct allocation of a frequency value x_n (n = 0,1, 2 ... 255) to the y_m value (m = 0, 1, 2 ... 204) of the sweep curve is thus given; see also Figure 2-8.

256 pixels are necessary for display of a sweep curve - 256 memory positions of 8 bits each contain a result curve.

This method of displaying the measured curves permits, in addition to specific selection of an x value (e.g. frequency markers) or y value (horizontal lines), storage of sweep curves for internal evaluation facilities such as "noise averaging" or "curve difference", and for external evaluation via the <IEC 625> Bus.

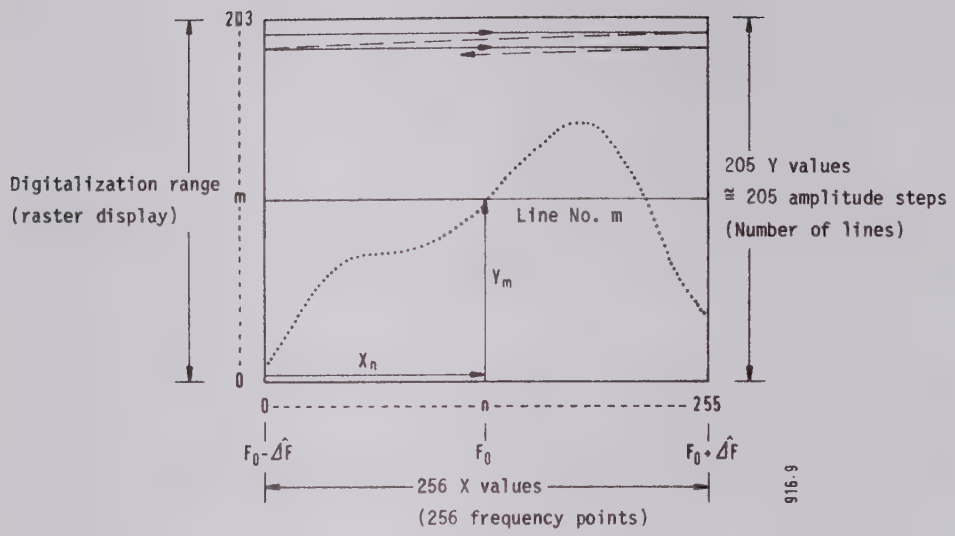


Figure 2-8 Principle of distortion curve display on the screen (raster display, no alphanumeric characters shown)

2.4 INTERFACE BUS <IEC 625>

The <IEC 625> Interface Bus is intended to permit control of microprocessor-controlled devices.

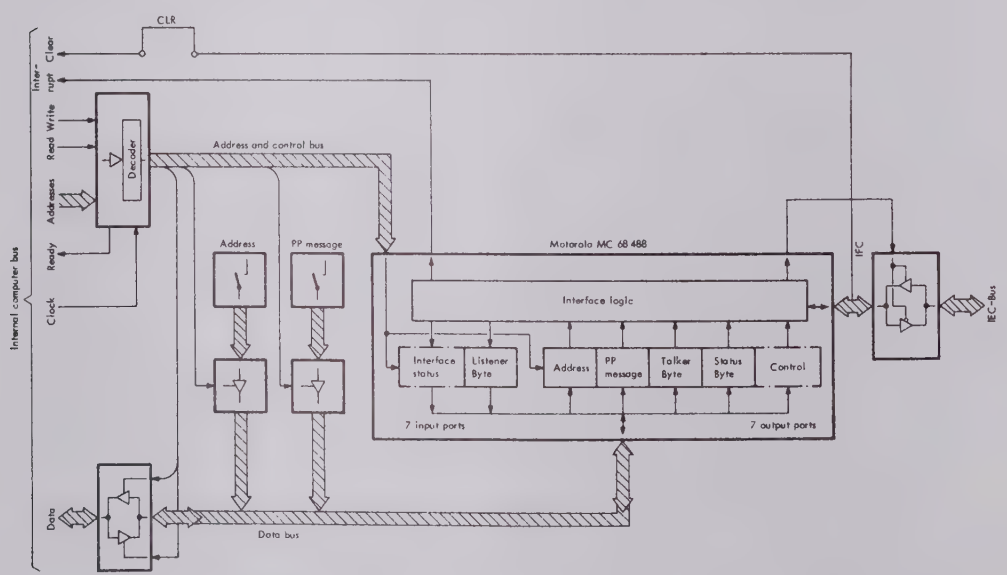


Figure 2-9 Block diagram of the <IEC 625> Interface Bus, BN 853/07

Figure 2-9 shows the simplified block diagram of the <IEC 625> Interface Bus board.

The interface to the IEC bus with the necessary driver and receiver circuits is shown on the right-hand side of the figure.

The comb connector to the input/output bus of the internal microprocessor is shown on the other side of the figure.

For the microprocessor, the IEC Bus Interface is nothing more than a collection of input ports and output ports. The exchange of data between the IEC Bus and the instrument is executed via these ports.

The exchange of data between the IEC Bus and the instrument is controlled by the IEC Bus program. The PROMs in which this program is stored are not located on the IEC Bus interface board, but within the instrument.

The actual interface logic is located in one IC, the IEC bus interface module MC 68 488 made by Motorola. This interface logic handles the major part of the interface tasks independently, i.e. without use of the internal microprocessor; for example, it automatically handles the IEC Bus handshake cycle and decodes all messages which are transferred on the IEC Bus. The interface states assumed as the result of these messages are written into the corresponding input ports. A further inport port is used as a transfer register for listener bytes. Listener bytes are data which are transferred from the IEC Bus to the instrument as long as the instrument is addressed as the listener; for example, when setting parameters for the instruments are being transferred.

In addition to the input ports, the module contains output ports which are used for:

- Reception of control commands with which the microprocessor can modify the behavior of the interface logic (for example, as one of many possibilities, it can stop the handshake cycle or transmit a service request SRQ via the IEC Bus).
- As transfer registers for bytes which must be transferred from the instrument to the IEC Bus, for example talker bytes and status byte.

Talker bytes are data which are transmitted from the instrument to the IEC bus as long as the instrument is operating as the talker, for example when it is transmitting results of measurement.

The status byte is the response of the instrument to a serial poll and contains the current instrument status.

The instrument address can be set up on the address switch.

With the aid of the "PP switch", it is possible to determine the data line of the IEC bus on which the device is to send its status bit SRQ if the controller executes a status interrogation by means of parallel poll.

2.4.1 COOPERATION BETWEEN INSTRUMENT AND IEC BUS INTERFACE

When the IEC Bus has reached a status in which operations by the internal microprocessor are necessary, the IEC Bus interface transmits an interrupt to the instrument. As a result of this interrupt, the microprocessor executes the IEC Nus program. This is always the case:

- Whenever the instrument is to be switched from manual control (local) to remote control (remote) or vice versa.
- Whenever a listener byte was transferred via the IEC Bus. The interface logic has then written this byte into the transfer register for listener bytes and stopped the handshake cycle. The handshake cycle remains interrupted until the microprocessor has read this byte (when DAC becomes true). After processing and storage of the listener byte, RFD = true is sent.

- Whenever the instrument has to provide a new talker byte. After the new talker byte has been written into the appropriate output port, the handshake cycle is restarted (DAC = true).
- Whenever a measurement is to be initiated in the instrument by means of the IEC Bus command "Device Trigger (GET)". The interface logic has again stopped the handshake cycle. This remains interrupted until the microprocessor has started the measurement and enabled the handshake cycle again (DAC = true and RFD = true).
- Whenever the instrument is to be set to a defined initial status by means of the IEC Bus command "Device Clear (DCL or SDC)". Again, the interface logic has stopped the handshake cycle and this remains interrupted until the microprocessor has set the instrument to the initial status and enabled the handshake cycle (with DAC = true and RFD = true).

If the wire strap CLR is fitted on the IEC Bus interface board, then the IEC Bus signal IFC (Interface Clear) causes initialization of the instrument. This permits the instrument to be initialized by the IEC Bus, even if its internal logic has "locked up". (This is important for instruments in unmanned stations, where a "lockup" state caused by external interference or faults cannot be cleared by switching the main voltage off and on again).

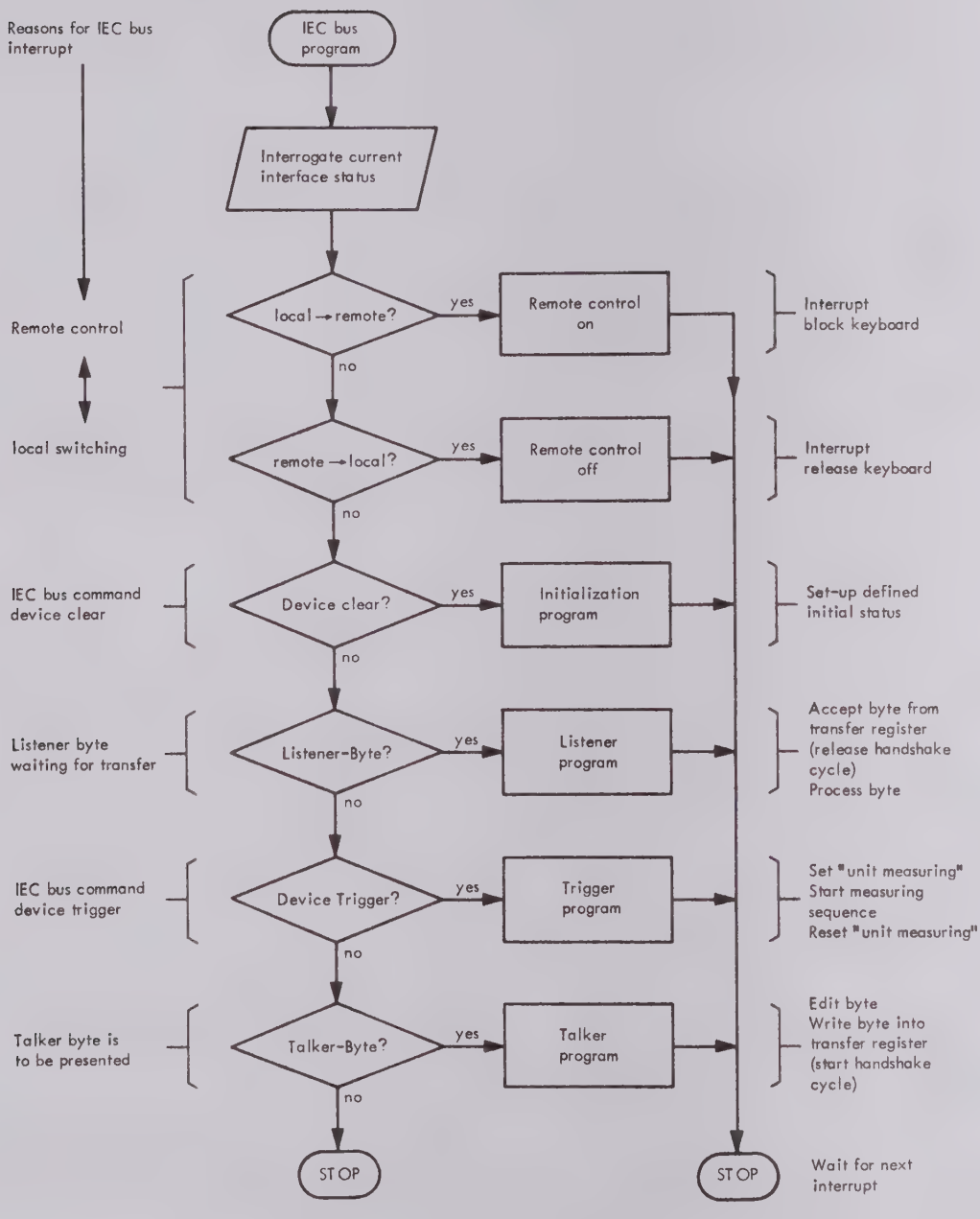


Figure 2-10 Structure of the IEC Bus program

Important Safety Instructions

A.C. power line voltage

The operating voltage of the instrument should be the same as the a.c. line voltage, so check whether or not the two voltages are equal.

Safety Class

This instrument is categorized as Safety Class I according to VDE 0411 or IEC Publ. 348. The power cord delivered with the equipment has a protective ground conductor. The a.c. power plug must be plugged into an a.c. power receptacle that has a third wire to ground, except in rooms that are particularly certified otherwise. Any disconnection of the protective ground conductor either inside or outside of the instrument is not permitted.

Connection to measuring circuits presenting hazards to personnel

Before the connection is made to a hazardous circuit, a protective ground connection, for protection against the measurement circuit, ought to be connected to the enclosure. In case the protective ground conductor of the a.c. power line can also assume this protective function, the a.c. power connection should be established first of all. If the measuring circuit has an inherent protective ground conductor, then this conductor must be connected to the enclosure before a connection is made to the measuring circuit.

Defects and Exceptional Conditions

When it can be assumed that safe operation is no longer possible, the equipment should be taken out of service and inadvertent operation should be prevented.
This occurs when
- the equipment shows external signs of damage
- the equipment no longer operates
- after being overstressed in any way (e.g. storage, transport) so that the tolerable limits are exceeded.

Fuses

Only specified fuses are permitted for use.

Opening the Instrument

After the covers have been removed or when components are removed with tools, certain components that operate with applied voltage could be exposed. And also connection points might be carrying a voltage.
Therefore, before the instrument is opened for inspection, all voltage sources should be disconnected.
But sometimes calibration, maintenance or repairs require that the instrument be open and operating with applied voltage. So only experienced craftspersons who understand the dangers associated with working on instruments that have exposed voltage points should undertake the job.
Capacitors can retain a voltage charge even after the instrument has been disconnected from voltage sources. Thus, the circuit diagrams should be observed.

Repairs, Replacement of Components

Repairs must be done according to correct technical practice. With that, particular attention must be paid to the characteristics of construction. None of the safety precautions should be changed, especially for leakage paths and air gaps, and separation by insulation must not be reduced.
Only original replacement parts ought to be used. Other replacement parts are only permitted if the safety and protection against human injury are not degraded through the use of non-original components.

Safety Testing after Repair and Maintenance

Testing of the protective ground conductor in the power cord for the instrument:

The resistance of the protective ground conductor shall be measured. It should be $<0.5\ \Omega$. The power cord should be bent and kinked during the measurement so as to reveal any intermittent connection. This gives evidence of a defective power cord.

Testing the insulation of the a.c. power circuit:

The insulation resistance is measured at 500 V between the a.c. power connection and the protective ground conductor connection. For this measurement, the instrument's power switch should be ON.
The insulation resistance ought to be $>2\ M\Omega$.

3 PUTTING INTO SERVICE AND OPERATION

3.1 UNPACKING THE INSTRUMENTS

The generator and the receiver of the measuring setup are shipped in separate special packing cases, which have been subject to comprehensive stress tests at Wandel & Goltermann.

This guarantees that the instruments will arrive without damage, even if subject to rough treatment. The instruments should be lifted carefully out of the packing materials at the appropriate side. We recommend that the original packing materials be saved for possible subsequent shipment. If this is not done, please see the following note.

3.1.1 SHIPPING NOTES

Shipping of the RMS-5 and RME-5 without damage can be guaranteed only by correctly designed packing materials. If the original packing materials have been lost, we recommend that the instruments be packed as shown in Figure 3-1.

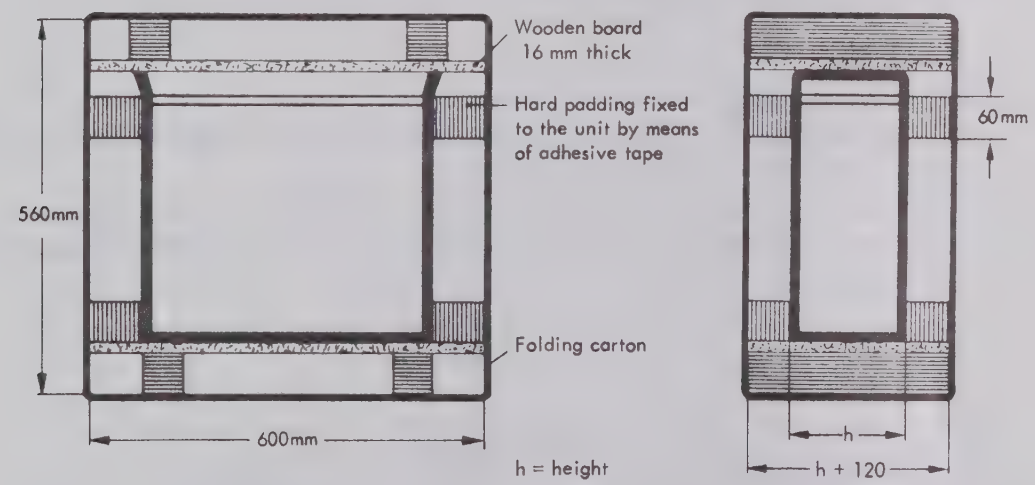


Figure 3-1 Packing notes

3.1.2 TRANSPORT IN THE TRANSPORT CASES TPK-3 (RMS-5) AND TPK-6 (RME-5)

The Transport Cases TPK-3 and TPK-6 protect the RM-5 against dust and mechanical damage during light transport (e.g. in a motor vehicle). They also provide suitable protection against water spray.

3.2 INSTALLING THE INSTRUMENTS

3.2.1 USE AS TABLETOP UNITS

The RMS-5 and RME-5 can be used as tabletop units in a horizontal position or, by folding out the leg, at a slight angle (front panel approximately 30° from the vertical). If the RMS-5 and RME-5 are placed on top of each other, the RMS-5 should be at the bottom.

The operating characteristics of the Radio-Link Measuring Setup RM-5 specified in Section 1 "TECHNICAL DATA" are valid only if the nominal operating conditions specified there are observed.

For use of the Measuring Setup at extremely high temperatures, a fan can be fitted on the rear of the instrument. Installation of this fan is simple and it can be removed quickly for transport of the Measuring Setup (e.g. in the Transport Cases TPK-3 and TPK-6).

The nominal operating temperatures are:

	RME-5 without fan	RME-5 with fan
up to 1000 m above sea level:	0 to +40 °C	0 to +50 °C
up to 3000 m above sea level:	0 to +30 °C	0 to +40 °C

3.2.2 USE IN 19" RACKS

The case dimensions of the RMS-5 and RME-5 are matched to the DIN standard 41 494 and the American standard ASA C 83.9 "Racks and front panels".

The instrument is therefore suitable for installation in 19" racks, the only necessary modification being the extension of the front panel width by fitting two mounting brackets as shown in Figure 3-2.

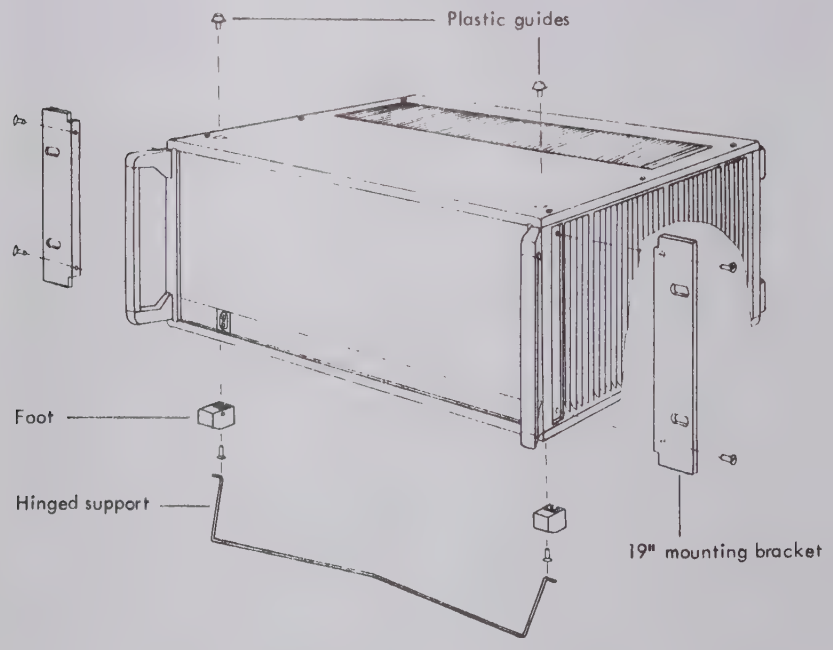


Figure 3-2 Converting the tabletop unit for rack installation

The complete 19" conversion kit, including mounting screws, is available with the following order numbers:

BN 700/00.03 (Generator RMS-5)
BN 700/00.06 (Receiver RME-5)

The feet on the bottom of the instruments and the locating studs on the tops of the instruments must be removed before installation (see also Figure 3-2).

Caution: When installing the instruments in cabinets, ensure that the upper limit of the nominal operating range for ambient temperature is not exceeded (see Section 3.2.1). Generally, the following measures are necessary: A gap of one height increment (44.4 mm) must be left free between the instruments.

In order to dissipate the heat generated in the cabinet, it may be necessary to fit fans. Suitable filters should be provided to prevent deposits of dust on the instruments.

3.3 MAINS CONNECTION AND SWITCHING ON

The instruments of the Radio-Link Measuring Setup RM-5 can be operated from AC mains supplies with frequencies between 47 and 63 Hz.

Note:
Before connecting the instruments of the Measuring Setup to the AC mains supply, check that the mains voltage selector (on the RMS-5) is set to the correct value and that the correct fuses are fitted.

Instrument	Mains voltage	Fuse
Generator RMS-5	220, 227, 235 V 110, 117, 127 V	T 0.5 B (0.5 A, slow-blow) T 1 B (1 A, slow-blow)
Receiver RME-5	96 to 261 V	T 3.15 B

When the instruments leave the factory, they are setfor operation from 220 V supplies, unless otherwise specified in the order form. For connection to supplies with voltages of 110, 117, 127, 227 and 235 V, the mains voltage selector on the rear of the RMS-5 must be set with the aid of a screwdriver to the required voltage value. This adjustment is not necessary on the RME-5, as its power supply unit is a switching regulator mounted on the right side of the instrument. The RME-5 can be operated from AC voltages between 96 and 261 V without switching.

In accordance with protection class I of VDE 0411 and IEC 348, the protective conductor contact of the mains plug is connected to the chassis of the instruments in the Radio-Link Measuring Setup, which means that the chasses are at ground potential when the instruments are connected to the mains supply.

Mains connection is carried out with the supplied mains cable. After depression of the power switch ("ON" position indicated by a red field in the switch cover), the instruments of the measuring setup are immediately ready for use. However, the Measuring Setup requires a warming up period of 30 minutes in order to achieve its full accuracy.

With the aid of the test described in Section 5.1 "Functional test", the Measuring Setup RM-5 can be checked for correct operation before measurements are started. Section 5.1.2 is particularly interesting, because it describes tests which require no additional test equipment. For these tests, the RMS-5 and RME-5 are operated back to back.

3.3.1 REPLACING FUSES

If none of the LEDs in the measuring frequency pushbuttons [8], [9] light when the RMS-5 is switched on or if the screen remains dark when the RME-5 is switched on, then the appropriate mains fuses should be checked. The positions of the instrument fuses are shown in Figures 3-3b and 3-4b.

Access to the fuse link is achieved by unscrewing the fuse cap. The electrical data of the fuse links to be used are shown in the table in Section 3.3.

Two spare fuse links for the appropriate mains voltages are carried in the accessory box on the rear of the instrument.

3.4 C O N T R O L S

3.4.1 GENERAL INTRODUCTION

The Radio-Link Measuring Setup RM-5 permits execution of all important measurements for assessment and for distortion adjustment at the BB and IF levels of radio-link and satellite systems and of subassemblies of such systems.

It consists of the two instruments:
- Generator RMS-5 and
- Receiver RME-5 with built-in screen.

The standard version of the measuring setup is equipped with the 70 MHz intermediate frequency (F_0); the version with the built-in 35 MHz intermediate frequency (Option) can be identified externally by the additional labels B (RMS-5) and E (RME-5).

Furthermore, it should be noted that two different series of test frequencies (f_M < 1 MHz) are possible when using the internal test frequencies "f_M". In various parts of the operating instructions, details which refer to test frequency settings therefore specify two values.

External identification of the actual test frequency series is provided on the RMS-5 by the inscriptions on the row of pushbuttons [8] for test frequency selection; on the RME-5, this identification is provided by label F on the front panel; (frequency values in MHz).

Any two frequencies (f_A) in the range 18 to 70 Hz can be selected for the sinusoidal sweep signal. The values are specified when ordering the Measuring Setup. In the normal version, the sweep frequencies 18 Hz and 70 Hz can be selected in the Generator RMS-5, the 18 Hz frequency being used primarily for measurements on satellite systems.

All important controls and indicators for normal operation, together with the measuring inputs and outputs, are arranged on the front panels of the RMS-5 and RME-5.

The mains connector, mains voltage selector (RMS-5), and the instrument fuse are located on the rear of the instruments, as are the connectors for the <IEC 625> Interface Bus or XY plotter (if this option is fitted) and the connector for the video signal for external display (printer, etc.).

The functions of the controls are described briefly in the following tables 3-1 and 3-3, the identification numbers and letters shown in Figures 3-3 and 3-4 being used. The numbers in square brackets in the tables and in the text are the same as those printed on the front and rear of the instrument.

Cross-references to the designations for the controls used in the circuit diagrams are provided in the right-hand column of the tables.

Setting up of the transmit parameters on the RMS-5 for the IF or BB output signal is carried out mainly with potentiometers and rotary switches, the test frequencies being selected by a row of pushbuttons.

The front panel of the Receiver RME-5 is divided horizontally into two parts. The upper part is subdivided into the sections "screen" (for result display) and pushbuttons for "distortion" and "evaluation". Between these are located the controls for special operating modes "frequency spectrum" and "frequency counter" and potentiometers for calibration and frequency response correction. The receive parameters are selected by means of pushbuttons, the basic functions being indicated by LEDs. The control panel "distortion" has two sets of pushbuttons [2] and [10] for selection of the required measured parameter and measuring range. Display of the sweep measurement result with the correct phase is carried out with the row of pushbuttons below these. Setting facilities for optimum screen display - potentiometer for curve offset, horizontal line insertion, etc. - are also found in this part of the front panel.

The pushbuttons "evaluation" control functions for optimum result display and evaluation aids for the measured curves selected with [2] and [10], such as "noise averaging", "curve difference", "curve analysis", and the "noise calculation device" which is currently in preparation (Option).

Parameters are modified on the RME-5 exclusively by pushbuttons (arrow pushbuttons), either in single step mode or continuously if the pushbutton is held down.

The lower part of the front panel contains the connection facilities for the IF and BB input signals with pushbuttons for selection of the required input, which is again indicated by an LED. LEDs with arrow markings indicate an input level which lies outside the measuring range. On the right side of this part of the front panel is the REMOTE indicator (LED on) which is on whenever the instrument is remotely controlled via the <IEC 625> Bus (or IEEE 488), where all front panel settings can be controlled by an external controller, which can also evaluate the results. The RME-5 can be controlled from the front panel again only after depression of the "LOCAL" pushbutton (LED off).

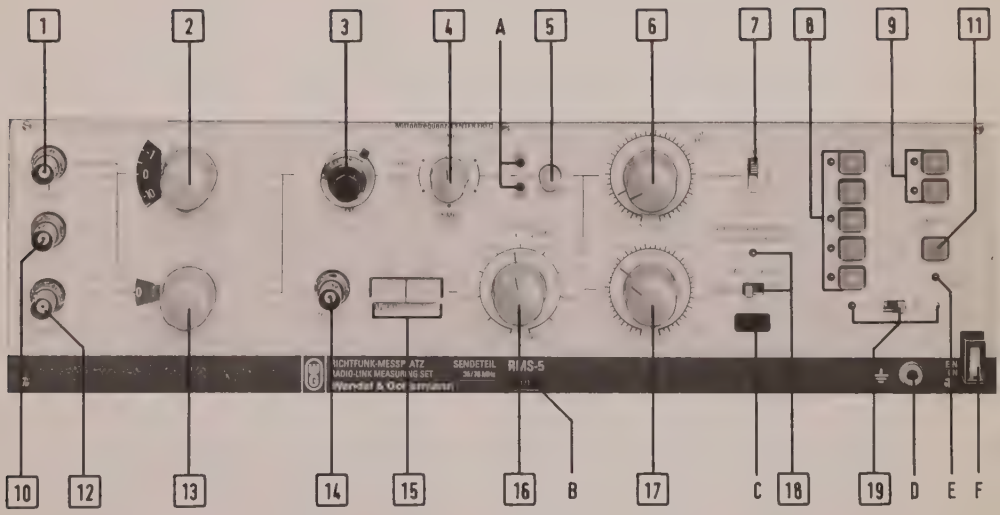


Figure 3-3a Front view of the Generator RMS-5

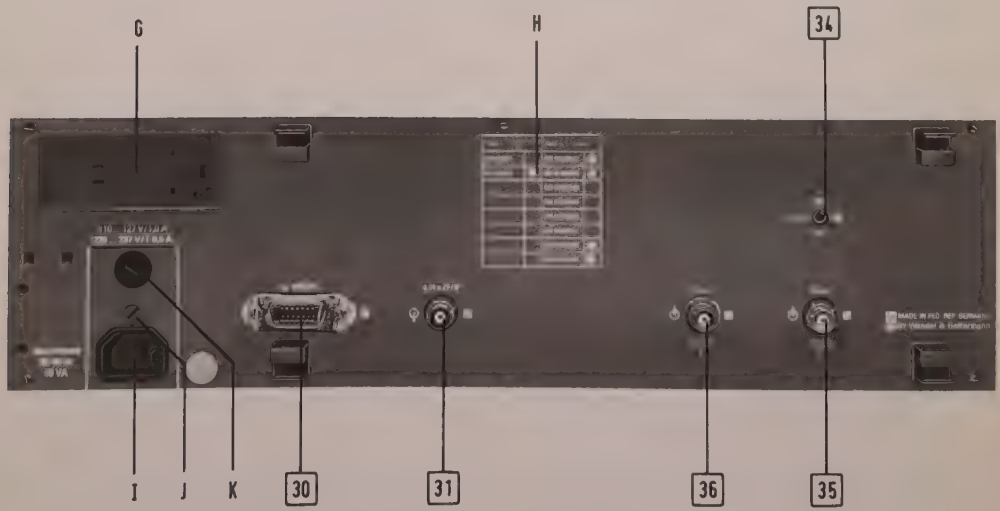


Figure 3-3b Rear view of the Generator RMS-5

3.4.2 GENERATOR RMS-5

Table 3-1a: Controls and connectors on the front of the RMS-5
(see Figure 3-3a on fold-out page)

Code number of control	Function	Abbreviation in circuit diagrams
[1]	Main IF output: Z_{out} = 75 Ω, level range -50 to + 10 dBm IF signal can be: - frequency-modulated and swept signal - unmodulated carrier (frequency response measurements) - frequency-modulated signal ($\hat{\Delta}F$ = 0 [7]).	5 Bu 1
[2]	Fine IF level adjustment, continuous in the range 0 to -10 dB.	12 P 1
[3]	10 turn helical potentiometer for IF center frequency offset (see Section 3.6.6).	9 P 7
[4]	Rotary switch, 3 positions per IF: - Selection of IF center frequency F_o = 70 MHz (35 MHz) - CAL: Calibration of IF center frequency (see 3.6.3) - VARIAB: IF center frequency offset (see 3.6.6).	9 S 3
[5]	Calibration potentiometer for fine tuning of selected IF center frequency (see 3.6.3).	8 P 2
[6]	Potentiometer for sweep width adjustment $\hat{\Delta}F$ of IF signal at outputs [1] and [10].	13 P 5
[7]	Slide switch with the positions: - $\hat{\Delta}F$: Sweep width adjustment with [6] according to scale - $\hat{\Delta}F/10$: Sweep width adjustment with high resolution (scale resolution times 10) - $\hat{\Delta}F = \hat{U}_A = 0$: Sweep width = 0, potentiometers [6] and [17] have no effect.	7 S 10
[8]	Row of pushbuttons for test frequencies f_M < 1 MHz.	7 S 1 ... 5
[9]	Pushbuttons for selection of test frequencies f_M > 1 MHz.	7 S 6, 7
[10]	Auxiliary IF output: Z_{out} = 75 Ω, level approx. -6 dBm; signal shape identical to that at output [1] - acts as control signal for receiver input P_I during P_{II} reception (RME-5).	5 Bu 2
[11]	Pushbutton for injecting the gap pulse into the sweep measurement result (to remove 180° phase uncertainty) (see 3.6.8).	7 S 8
[12]	IF output: Output for crystal-controlled signal of 70 MHz (35 MHz), Z_{out} = 75 Ω; Level: +5 dBm (option "IF calibration generator").	18 Bu 1
[13]	IF level control "coarse", adjustable in 10 dB steps from -40 to +10 dBm.	6 EL 1

Code number of control	Function	Abbreviation in circuit diagrams
[14]	BB output: Z_{out} = 75 Ω, BB signal $\hat{U}_A + U_M$.	16 Bu 5
[15]	Attenuator switches:	
	Attenuation of $\hat{U}_A + U_M$ by 20 dB	16 S1/1
	Attenuation of U_M by 20 dB.	16 S1/2
[16]	Potentiometer: - for setting the RMS value U_M of the test voltage (0 to 500 mV) - for setting the r.m.s. value test deviation of Δf the IF signal (0 to 500 kHz).	15 P 1
[17]	Potentiometer for setting the sweep voltage $\hat{U}_A$ of the BB output signal at socket [14] $\hat{U}_A$: 0 to $\pm$2.5 V.	16 P 5
[18]	Slide switch for activating the "automatic sweep width reduction" (see 3.6.5).	7 S 11
[19]	Slide switch for setting sweep frequency "f_A": 18 Hz or 70 Hz.	
A	Limit value indicators for calibration of IF center frequency (see 3.6.3).	9 Gl 9, 10
B	Specification of built-in IF (35 MHz IF as Option).	
C	Indicator "$f_M > \Delta\hat{F}$" in the case of an invalid combination of sweep width and measuring frequency.	
D	Ground socket	
E	LED for recognition of operation with external measuring and sweep signals.	7 Gl 8
F	Power switch	

Table 3-1a Controls and connectors on the front panel of the RMS-5

Code number of control	Function	Abbreviation in circuit diagrams
[30]	Socket, 14-pole, for remote control of test frequency.	7 Bu 1
[31]	Output 0.01 x IF for connection of frequency counter.	8 Bu 2
[34]	Switch "INT/EXT" - Normal operation in position "INT"; set to position "EXT" for use of external test and sweep signals.	9 S 1
[35]	Input for external sinusoidal sweep signal (f_A = 18 to 70 Hz).	9 Bu 1
[36]	Input for external sinusoidal test signal (f_M = 25 kHz to 5.6 MHz).	16 Bu 6
G	Accessory box for spare fuses, wrench for Versacon® 9 inserts, hexagon wrench for removal of covers, and board extractor.	
H	Table with details of Options fitted.	
I	Mains connector	
J	Mains voltage selector	
K	Mains fuse	

Table 3-1b Connectors on the rear of the RMS-5

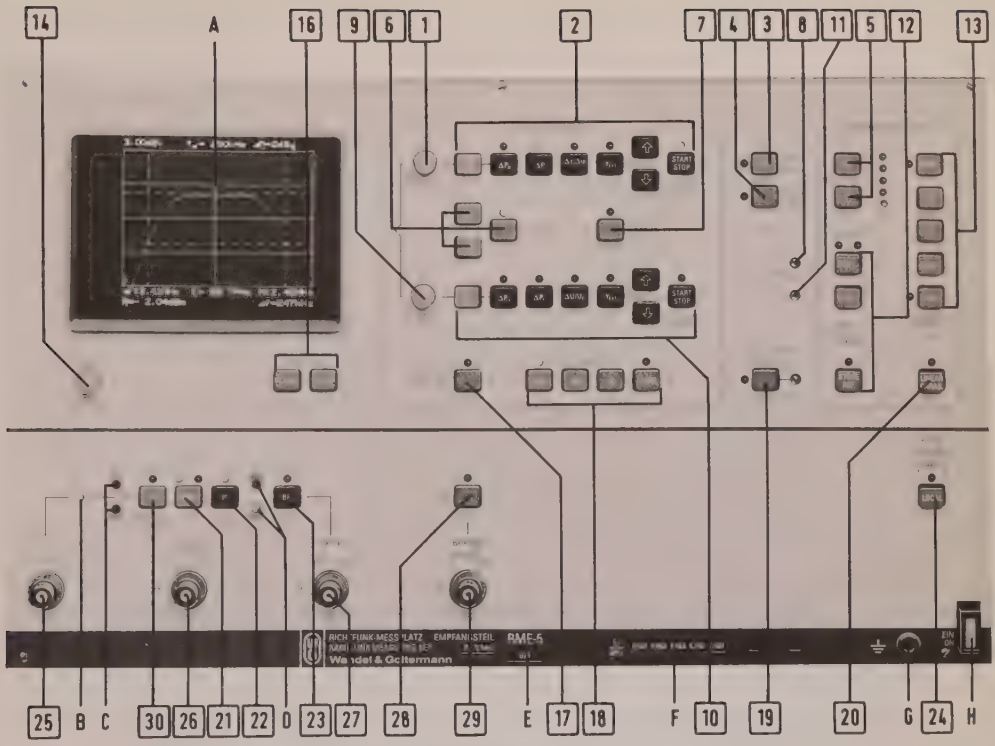
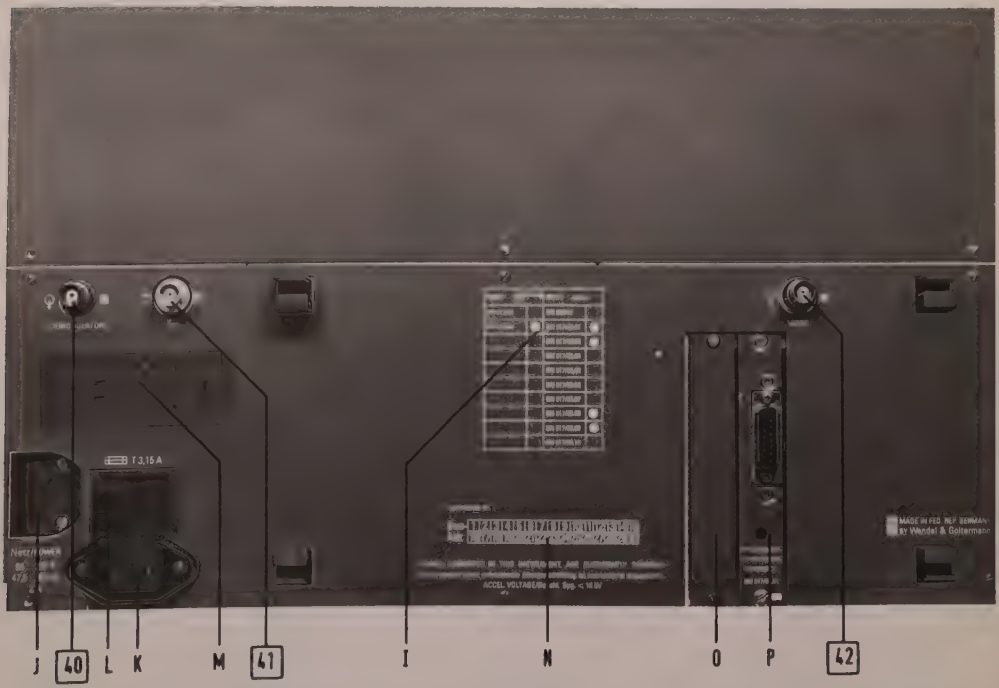


Figure 3-4a Front view of the Receiver RME-5



B Figure 3-4b Rear view of the Receiver RME-5

3.4.3 RECEIVER RME-5

Code number of control	Pushbutton	Function	Abbreviation in circuit diagrams
[1]		Potentiometer for vertical displacement of selected sweep measurement results [2].	10 P 11
[2]		Pushbuttons, one for each measuring mode to be called up, see Section 3.4.3.1.	27 S 35 ... 38 27 G1 17 ... 20
	ΔP_{II}	"IF frequency response" (selective), test signal at input P_{II} [26] with IF reference signal at input P_I [25]; "IF return loss measurement"	
	ΔP_I	"IF frequency response" (wideband), test signal at input P_I [25].	
	$\Delta\tau, \Delta\varphi$	"Group delay"/"Differential phase" Test signal at IF input P_I [25] or BB input [27].	
	Y_{ext}	"Y_{extern}", external sweep measurement result connected to input [41].	
	⇧ ⇩	Direction pushbuttons for range switching.	27 S 29, 30
	START STOP	Pushbutton for starting the plotter function (XY plotter interface) or for freezing the video display.	27 S 28 27 G1 36
	ON OFF	Pushbutton for switching off the current measuring mode [2].	27 S 43
[3]		Pushbutton for selection of operating mode "BESSEL SPECTRUM", spectral display of IF signal.	27 S 41 27 G1 15
[4]		Pushbutton for "frequency counter function" for measurement of unswept IF signals.	27 S 40 27 G1 14
[5]	⇧ ⇩	Direction pushbuttons for setting the noise averaging factor in accordance with LED display.	27 S 23, 27 27 G1 37 ... 41
[6]		Pushbutton for display of horizontal lines.	27 S 10 ... 12
	⇧⇩ ⇩⇧	Arrow pushbuttons for changing the horizontal line spacing.	27 G1 51
[7]		Selection of 300 Hz bandwidth for evaluation of sweep signal.	27 S 19 27 G1 31
[8]		Potentiometer for calibration of IF level meter (see 3.6.4).	10 P 34
[9]		Potentiometer for vertical displacement of selected sweep measurement results [10].	10 P 12

Code number of control	Pushbutton	Function	Abbreviation in circuit diagrams
[10]		Pushbuttons for selection of a second sweep measurement result;	27 S 24 ... 26
	$\Delta U/U_0$	Measuring modes are the same as with pushbuttons [2] except for distortion parameters "linear distortion"/"differential gain", see Section 3.4.2.1.	S 31 ... 34, 42 27 Gl 20 ... 24 Gl 35
[11]		Potentiometer for calibration of the r.m.s. value deviation meter in the function "BESSEL SPECT" (see Section 3.6.4).	
[12]		Pushbuttons for generation of "curve difference" (NORMALIZER), see 3.7.2.	27 S 6 ... 8 27 Gl 42 ... 44
	STORE REF	Storage of reference curve.	
	DISPL.	Call-up of "difference curve" or "reference curve".	
	OFF	Display of current sweep measurement result.	
[13]		Pushbuttons for the Option "noise calculation" (in preparation).	
[14]		Potentiometer for adjustment of screen intensity.	29 P 1
[16]	⇨ ⇦	Pair of pushbuttons for shifting the frequency markers "M" (vertical lines).	19 S 1, 2
	⇦ ⇨		
[17]		Pushbutton for display of forward and backward traces of sweep curve.	27 S 17 27 Gl 30
[18]		Pushbuttons for phase correction of deflection voltage U_x (see 3.6.7).	27 S 13 27 Gl 26, 27
	U_x(IF)	Deflection voltage recovered from IF signal.	
	⇦	Pair of pushbuttons for shifting the phase of U_x: U_x (IF): $\pm 6°$, U_x (BB): $\pm 180°$.	
	⇨		
	U_x(BB)	Deflection voltage recovered from BB signal.	
[19]		Pushbutton for linear frequency response correction ΔP_I by means of the corresponding potentiometer.	27 S 20 27 Gl 32
[20]	LIN. PARAB	Pushbutton for evaluation of sweep curves on the basis of linear and parabolic components; the results are inserted in the sweep curve.	27 S 9 27 Gl 45

Code number of control	Pushbutton	Function	Abbreviation in circuit diagrams
[21]	IF/MHz	IF center frequency selection: 70 MHz or 35 MHz.	27 S 45 27 Gl 9, 10
[22]	IF	Pushbutton for IF mode, activation of inputs P_I and P_{II}.	27 S 16 27 Gl 28
[23]	BF	Pushbutton for BB mode ($\Delta\tau$, $\Delta\varphi$, and $\Delta U/U_o$ measurement), active input socket [27].	27 S 15 27 Gl 27
[24]	LOCAL	Pushbutton for switching to local mode during remote control.	27 S 44 27 Gl 16
[25]		IF input P_I, Z_{in} = 75 Ω, for the following signals: - frequency-modulated and swept signal ($\Delta\tau$, $\Delta\varphi$, and $\Delta U/U_o$ measurements) - unmodulated, swept carrier (ΔP_I measurement) - frequency-modulated, unswept signal.	2 Bu 1

Code number of control	Function	Abbreviation in circuit diagram
[26]	IF input P_{II}, Z_{in} = 75 Ω, for frequency response measurement ΔP_{II} with large attenuation differences and return loss measurement; IF reference signal at input P_I.	8 Bu 1
[27]	BB input, Z_{in} = 75 Ω, test signal is the sum signal $\hat{U}_A + U_M$ coming from the unit being tested; input active when pushbutton [23] is depressed.	5 Bu 2
[28]	Pushbutton for function "BB level meter", activating input [29].	27 S 39 27 Gl 50
[29]	BB level input, Z_{in} = 75 Ω; for level measurement of unswept signals in the range 10 kHz to 8.5 MHz.	18 Bu 1
[30]	Pushbutton for switching off "automatic IF level matching" (LED on).	27 S 46 27 Gl 52
A	Video screen for display of all results: - Sweep curves and auxiliary lines for result evaluation with the actual parameters above and below the curve - Spectral display of the IF signal (frequency window) - Monitor display "frequency counter function" and "BB level meter function".	
B	AFC lamp: lights when input frequency lies within the capture and holding range 45 to 95 MHz (25 to 45 MHz).	27 Gl 13
C	Indication (LED on) when IF input level lies outside the nominal range.	27 Gl 11, 12

Code number of control	Function	Abbreviation in circuit diagrams
D	Indication when the BB input level (distortion measurements) at socket [27] is outside the nominal range.	27 Gl 48, 49
E	Specification of built-in IF (35 MHz Option).	
F	Specification of built-in measuring frequency series (Series I or II, possibly color sub-carrier frequency).	
G	Ground socket	
H	Power switch	1 S 1

Table 3-2a Controls and connectors on the front of the RME-5 (see Figure 3-4a on fold out page)

Code number of control	Function	Abbreviation in circuit diagrams
[40]	Demodulator output for external processing of the test signal U_M.	5 Bu 6
[41]	Input for low frequency signal "Y_{extern}" for evaluation in RME-5; R_i = 10 kΩ, measuring range 8 to 800 mV.	10 Bu 2
[42]	Output for video signal for external display of results (video printer, large screen monitor).	19 Bu 7
I	Table of built-in Options (BN numbers).	
J	Battery compartment for Ni-Cd cells for retaining memory contents when the instrument is switched off.	
K	Mains connector	1 St 1
L	Mains fuse	
M	Accessory box for spare fuse, wrench for Versacon® 9 inserts, hexagon wrench for removal of covers, and board extractor.	
N	Signature list number of address bus.	
O	Insertion position for noise calculation device (Option, currently in preparation).	
P	XY plotter interface, inserted instead of Interface Bus <IEC 625>.	22 St 1

Table 3-2b Connectors and miscellaneous items on the rear of the RME-5 (see Figure 3-4b)

3.4.3.1 Pushbuttons [2] and [10], "distortion results"

The pusbutton rows [2] and [10] permit simultaneous display (recall) of two sets of sweep measurement results. One measuring mode can be selected in each row of pushbuttons - see Figure 3-5 - and the selected measuring mode is identified by the corresponding LED (on). Each of the

two rows of pushbuttons has the same layout, and the two rows differ only in the measuring modes "$\Delta\tau,\Delta\varphi$" and "$\Delta U/U_o$". As the pushbuttons "ΔP_{II}", "ΔP_I" and "Y_{EXT}" are provided in both rows, it is possible, in addition to simultaneous display of "$\Delta\tau,\Delta\varphi$" with "$\Delta U/U_o$", to select combinations such as the "$\Delta\tau,\Delta\varphi$" result together with the "ΔP_{II}", "ΔP_I" or "Y_{EXT}" result. The same applies to the "$\Delta U/U_o$" result selected with [10] and the other results selected with row [2]. This facility for free combination of any required measuring modes is extremely useful for practical operations.

The sweep curve can be shifted continuously in the vertical direction with the potentiometers [1] and [9]. The position of the second curve is not affected by this.

If only a sweep result is desired, then the unwanted result can be switched off with the "ON/-OFF" pushbutton; the corresponding LED is then switched off.

The range of the selected measuring mode (in the same row) can be modified step-by-step with the direction pushbuttons "⇧", "⇩".

Depression of "⇧" raises the range by one step
Depression of "⇩" lowers the range by one step

The actual range per division (DIV) is always displayed on the screen alongside the corresponding measuring mode, which appears in the upper line of the screen. The measuring mode [2] is displayed on the left of the line and the measuring mode called-up with pushbutton row [10] is displayed on the right.

The pushbutton function"START/STOP" triggers the XY plotter for recording of the actual result selected in the same row of pushbuttons; see Section 3.9.2.

If the XY plotter cable is not connected to the interface, depression of the "START/STOP" pushbutton freezes the screen display (LED on).

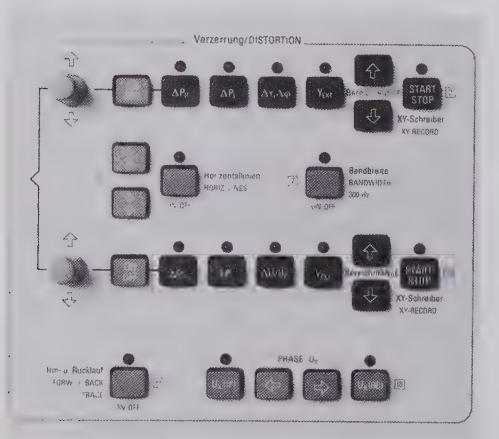


Figure 3-5 Part of the RME-5 front panel: Pushbutton rows [2] and [10] for calling-up distortion results

3.5 OPERATING MODES AND RESULT DISPLAY ON THE MONITOR OF THE RME-5

3.5.1 DISTORTION RESULTS [2], [10]

The distortion results (sweep measurement results) which can be displayed on the monitor include:

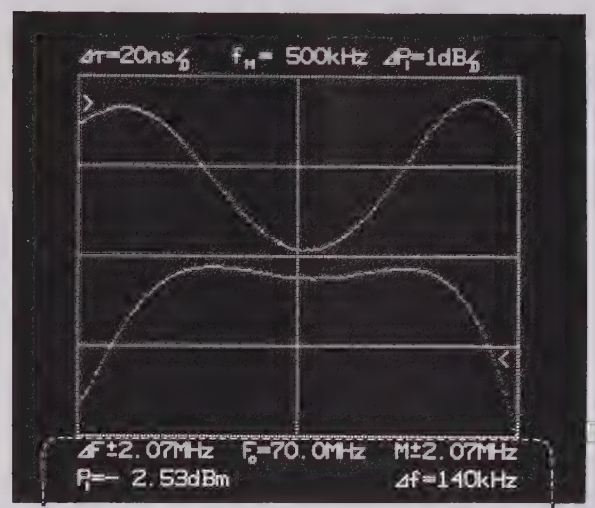
- "$\Delta\tau$" group delay or "$\Delta\varphi$" differential phase
- "$\Delta U/U_o$" linear distortion or differential gain
- "ΔP_I" Attenuation frequency distortion (IF frequency response)
- "ΔP_{II}" Attenuation frequency distortion (IF frequency response) selective measurement of large attenuation differences,
  IF return loss measurement (a_r)
- "Y_{EXT}" display of low frequency signals which are related to the sweep signal of the RM-5.

If the measuring frequency f_M is less than 1 MHz, then group delay measurement ($\Delta\tau$) is automatically executed if the result "$\Delta\tau, \Delta\varphi$" is selected; at $f_M > 1$ MHz, the "differential phase" ($\Delta\varphi$) is measured.

3.5.1.1 Operating sequence, settings on the RM-5

	IF Measurement	BB Measurement
RMS-5		
Settings	[2], [13] : P_I	
	[4] : F_o	
	[6] : ΔF	
	[16] : Δf	[16] : U_M
	[19] : f_A	[17] : $\hat{U}_A$
Pushbutton function	[8], ([9]) : f_M	[8], ([9]) : f_M
Active output	[1]	[14] : $\hat{U}_A + U_M$
	[10], ([1])	[14], ([1])
RME-5		
Pushbutton functions	[2], ([10]) : Mode	[2], ([10]) : Mode
	[22] : "IF"	[23] : "BB"
	[21] : "IF/MHz"	
Active input	[25] : P_I	[27]
	[26], ([25]) : P_{II}, P_I	[27], [25]* : BB, P_I U_x (IF)
Monitor display	Figure 3-6*	Figure 3-6 Figure 3-6*

3.5.1.2 Monitor display of "distortion results"



Mode [2] (Range) - Test frequency
- Mode [10] (Range)

Graphic display with sweep curve [2] 1)
with sweep curve [10] 1)

- IF center frequency
Sweep width
IF level at (F_o)
- Frequency markers
- R.M.S test frequency deviation

* Displayed only if IF socket P_I receives a signal

Figure 3-6 Screen layout in distortion measurement mode
3-6* Information in bottom lines of screen

3.5.1.3 Status message "SWEEP SIGNAL TOO LOW"

Display of the status message within the graphic area:

- without display of curves, signals the current operating status of the RME-5 or draws the operator's attention to invalid receive parameters.

The message is displayed
momentarily (until the instrument has settled) when:
- the instrument is switched on
- the instrument is switched from the mode "BESSEL SPECT", "IF COUNTER", "BB LEVEL" to "DISTORTION [2], [10]".

---

1) Arrow on left edge of screen - mode [2] - and right edge of screen - mode [10] - for identification of the distortion curves

Continuously if:
- the sweep width ΔF, $\hat{U}_A$ is too small
- the input level is too low.

3.5.1.4 Frequency markers "M"

For evaluation of the sweep measurement results $\Delta\tau$ or $\Delta\varphi$, $\Delta U/U_o$, ΔP_I ΔP_{II}, or Y_{EXT}, if the IF input signal [25] is used, the x axis of the screen can be further subdivided and simultaneously calibrated with a pair of vertical lines (dotted) which are positioned symmetrically with respect to the center frequency "F_o". The distance between the lines can be adjusted in a pseudo-continuous manner over the whole sweep width range; the value range of the frequency markers is: $\sim 0.1\ \Delta F \leq M \leq \Delta F$. The pushbuttons [16] FREQ. MARK have the following effect:

" ⇨ ⇦ " Reduces the spacing
" ⇦ ⇨ " Increases the spacing

The actual value of the frequency markers is displayed in the lower line of the screen; see Figure 3-7.

When switched, the frequency markers are first positioned at the sweep limits ($M = \Delta F$) and are therefore not visible. For display of the markers, the pair of lines must be shifted into the sweep range with the " ⇨ ⇦ " pushbutton, which must be held down until the lines appear. Fine adjustment of the frequency markers is carried out by momentarily depressing the pushbuttons "⇨ ⇦" "⇦ ⇨" to move the vertical lines to the required position on the screen.

3.5.1.5 Horizontal lines

Similarly, the y axis of the screen can be subdivided for evaluation purposes with moveable horizontal lines (dotted), the lines being arranged symmetrically with respect to the center line; see Figure 3-7. This makes it possible to insert a tolerance band in one sweep measurement result or determine extreme values of the curve. The spacing "$\hat{=}$" of the horizontal lines is also displayed numerically above the graphic area of the screen (at the left). If the horizontal lines are used, then only one sweep measurement result selected with pushbuttons [2] or [10] can be displayed. If two sweep curves are displayed and the horizontal lines switched on, the result which was selected with pushbuttons [10] is erased. The result selected with [2] has priority.

The horizontal lines are switched on and off with the pushbutton "ON/OFF" [6] (LED on). Their initial position coincides with the horizontal center line: "$\hat{=}$" = 0. The spacing is modified with the arrow pushbuttons under [6]:

" ⇧ ⇩ " Increases the spacing; limits ≙ upper and lower graticule lines
" ⇩ ⇧ " Reduces the spacing

If either of the arrow pushbuttons is held down, the line spacing is increased or decreased in a pseudo-continuous manner. Fine adjustment is best carried out by momentarily depressing the pushbuttons.

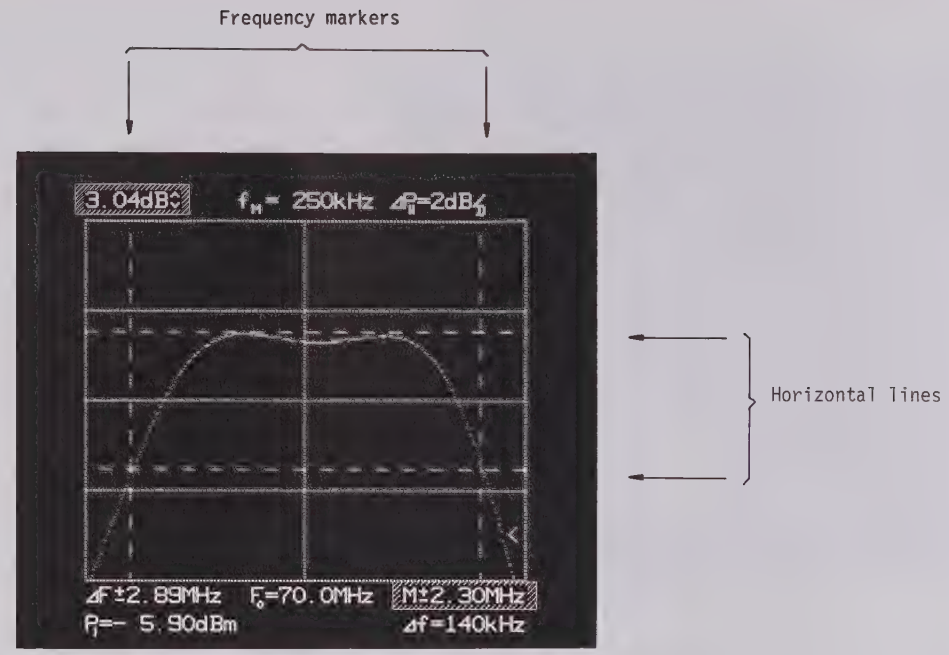


Figure 3-7 Sweep measurement result with frequency markers "M" and horizontal lines "⌃"

3.5.2 OPERATING MODE "BESSEL SPECTRUM [3]" - MONITOR DISPLAY

In the operating mode "BESSEL SPECT.▽" - pushbutton function [3] of the RME-5 - the IF signal connected to the P_I input [25] is displayed in its spectral form; the RME-5 operates as a spectrum analyser; see also Section 4.2. The bandwidth at all test frequencies is approximately 800 kHz, which is sufficient to display the first side line at the test frequency f_M = 250 kHz (or 277.8 kHz). This operating mode is intended for calibration of the r.m.s. value deviation meter (see Section 3.6.4) and for adjustment work on modulators and demodulators (slope).

In the monitor display of the FM spectrum, the bottom text line displays the selected test frequency "f_M", the r.m.s. value test deviation at bessel null (η = 2.405)[1] "Δf_o", and the currently set r.m.s. value deviation "Δf"; see Figure 3-8, example f_M = 83.3 kHz.

1) η: Phase deviation (= $\hat{\Delta f}/f_M$), η = 2.405 corresponds to first bessel null position

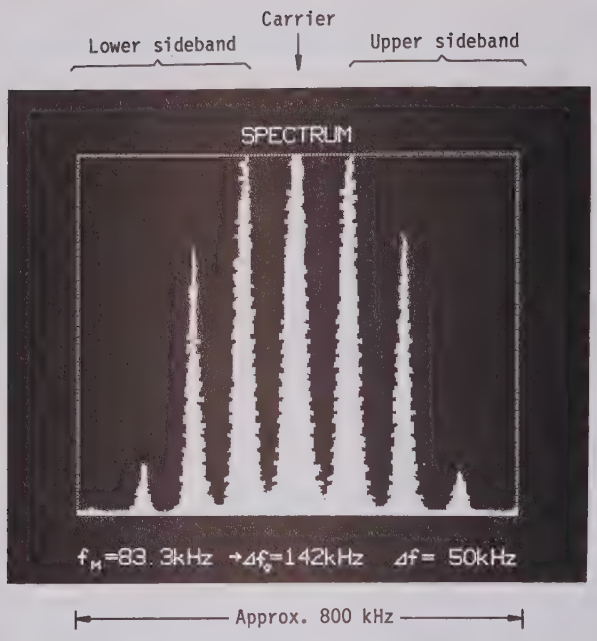


Figure 3-8 Monitor display "BESSEL SPECT.▽", pushbutton function [3]

3.5.3. OPERATING MODE "IF COUNTER" [4] - MONITOR DISPLAY

The frequency counter within the RME-5 can be used for frequency measurement of unswept IF signals in the range 25 to 95 MHz. The signal to be measured, which is connected to input P_I [25] - note the level range - is displayed in digital form with a resolution of 0.01 MHz. The operating mode is selected with pushbutton function [4]. The frequency value F_o is displayed under the heading IF-INPUT P_I as shown in Figure 3-9. In addition to the frequency, the IF level P_I is also displayed. If the signal being measured is an FM signal (e.g. from the RMS-5), then the r.m.s. value test deviation Δf is also shown.

The frequency counter is also useful for setting an IF center frequency other than 70 MHz (35 MHz); settings on the RMS-5: [3], [4]: VARIAB.

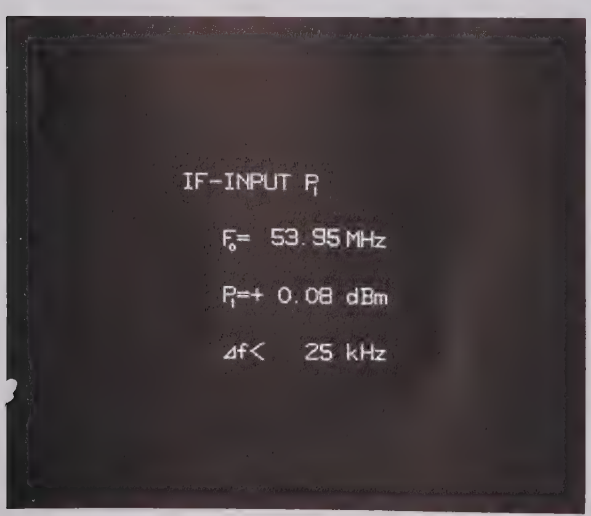


Figure 3-9 Monitor display "IF COUNTER", pushbutton function [4] of the RME-5

3.5.4 OPERATING MODE "BB LEVEL METER [28]" - MONITOR DISPLAY

The frequency range of the BB level meter extends from 10 kHz to 8.5 MHz, and its measuring range extends from -50 to -10 dBm.

The BB level meter is calibrated automatically.

The signal to be measured is connected to the "BB level input", socket [29], and the level meter is switched on by depressing pushbutton [28] (ON/OFF); the corresponding LED lights.

In the monitor display, an example of which is shown in Figure 3-10, the power level of the signal appears in four digits with a resolution of 0.01 dB. A value above or below the measuring range of the instrument is indicated by display of "> -10 dBm" or "< -50 dBm", respectively.

Of the possible applications of the RM-5 mentioned in Section 3.8, the BB level meter can be used in the following cases:

3.4.2.2 Adjustment of modulator slope
3.8.5.1 Adjustment of demodulator slope

If these measurements are carried out as a check on operational systems, care must be taken that no further signal (such as a pilot) is connected to the BB level input [29] in addition to the signal to be measured, as the wideband BB level meter of the RME-5 would display the sum of both signals. Signals $\leq$ 100 Hz (e.g. the sweep signal U_A) are an exception; these are ignored by the level meter.

Due to the pseudo - RMS calibration of the BB level meter, it is also possible to measure wideband sum signals, for example the total system power at a decoupled BB measuring output or the total level of a noise signal.

The BB level meter is switched off by depressing pushbutton [28] (LED off). The screen display shown in Figure 3-10 disappears, and the monitor display of the previously selected function (of the input selected with [22] or [23]) appears again. The last input which was used remains active even during BB level measurement (pushbutton function [28]).

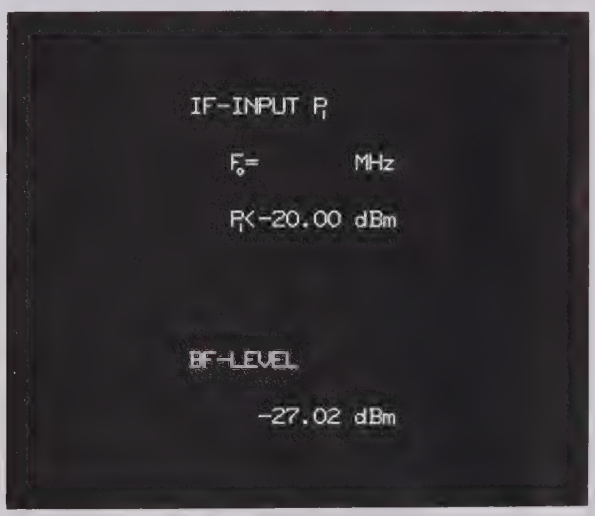


Figure 3-10 Monitor display "BB level meter", pushbutton function [28] of the RME-5

3.6 BASIC SETTINGS OF THE RM-5 BEFORE STARTING MEASUREMENTS

3.6.1 OPERATION WITH INTERNAL OR EXTERNAL TEST AND SWEEP SIGNALS

For normal operation of the RM-5 with internal test and sweep signals, switch [34] on the rear of the RMS-5 is set to the position "INT.".

Operation with external test and sweep signals within the permitted frequency ranges is possible in the position "EXT."; LED E on the front panel lights.

The external frequencies are connected to the internal frequency modulator via the sockets [36] (test signal $U_{M\ EXT}$) and [35] (sweep signal $U_{A\ EXT}$) on the rear of the RMS-5.

For both inputs, the modulator slope is 10 MHz/V.

3.6.2 ADJUSTMENT OF THE DISPLAY

As the display operates on the video principle, it requires no special adjustments such as position of the display or contrast of the sweep curves. The internal adjustment is so stable that no regular operator adjustment is necessary.

The brightness of the video display, which is always free of flicker, can be adjusted with potentiometer [14], which also permits adjustment for photography of the screen display.

3.6.3 CALIBRATION OF THE IF CENTER FREQUENCY ON THE RMS-5

Particularly during the warming-up period (approximately 30 min), it is necessary to check the IF center frequency of 70 MHz (or 35 MHz as option) and to calibrate it as necessary.

Calibration is carried out as follows:

- Set rotary switch [14] of the RMS-5 to the position "·CAL" of the required IF.
- Adjust potentiometer [5] until the corresponding LEDs A are both off.
- Return switch [4] to its center position.

Note: If external test and sweep signals are used, i.e. switch [34] is in position "EXT.", calibration of the IF center frequency is possible only if no sweep signal is connected to input [35] during calibration.

During calibration of the IF center frequency, the output signal at the IF outputs [1] and [10] is switched off. In the case of measurements on operational systems, an IF standby generator in the system can hold the channel during calibration.

3.6.4 CALIBRATION OF THE IF LEVEL METER AND R.M.S. VALUE DEVIATION METER

Precise IF level and r.m.s. value deviation measurements are possible only after calibration of the IF level and r.m.s. value deviation meter. For this adjustment, the RMS-5 and the RME-5 are connected back to back by connecting socket [1] of the RMS-5 to socket [25] of the RME-5.

Calibration of the IF level meter is carried out with an IF level of 0 dBm; calibration of the r.m.s. value deviation meter is carried out with the aid of the Bessel method at a test frequency f_M = 250 kHz (or 277.8 kHz). If pushbutton [3] "BESSEL SPECT.▽" is depressed, the RME-5 operates as a spectrum analyser. See also Sections 3.5.2 and 4.2.

3.6.4.1 Calibration of the IF level meter (P_I calibration)

Set up the RMS-5 and RME-5 as shown in the following tables:

Settings on the RMS-5			Pushbutton functions on the RME-5 (LED on)		
[2]	:	0 dBm	[22]	:	"IF" (IF measurement)
[13]	:	0 dBm (-10 dBm)	[21]	:	"IF/MHz" LED 70 (or LED 35)
[4]	:	70 MHz (or 35 MHz)	[4]	:	Monitor display "IF-INPUT P_I"
[16]	:	0 V			
[7]	:	$\hat{\Delta F}$ = 0			

- Compare the level value "P_I" displayed on the screen of the RME-5 with the level set up on the generator (0 dBm).
- If the displayed value is not 0 dBm, adjust potentiometer [8] "CAL, P_I" on the RME-5 with a suitable screwdriver until the screen display becomes P_I = 0.00 dBm.

3.6.4.2 Calibration of the IF r.m.s value deviation meter (Δf calibration)

- Set up the RMS-5 and the RME-5 as for calibration of the IF level meter. Selection of the test frequency: pushbutton function "0.25" (or "0.277"): f_M = 250 kHz (or 277kHz). Monitor display "BESSEL SPECT.∇" - pushbutton function [3] of the RME-5: unmodulated IF carrier (see Figure 3-11a) and the test deviation Δf_o = 425 kHz (or 472 kHz) to be set for carrier suppression (Bessel zero) are displayed. The actual test deviation Δf is displayed on the right of the screen.

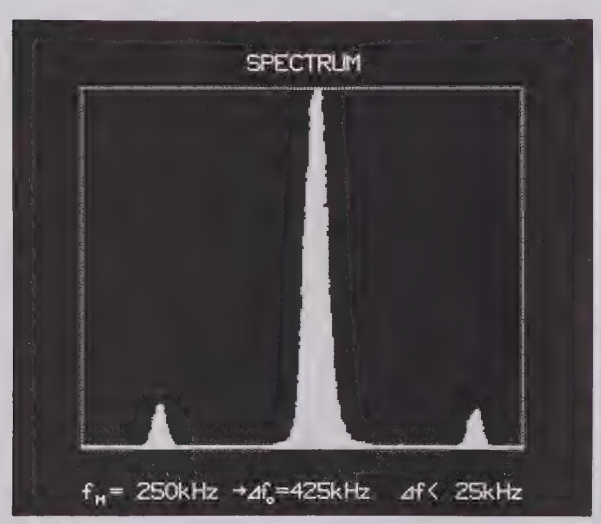


Figure 3-11a Weakly modulated IF carrier, phase deviation $\eta << 1$

- Increase the test deviation with potentiometer [16] of the RMS-5 until the carrier disappears (and the sidelines reach their maximum value); see Figure 3-11b.

- Compare the actual test deviation Δf (in Figure 3-11b: 421 kHz) with the theoretical value Δf_0.
- If the values differ, adjust potentiometer [11] "∇CAL. Δf" until the displayed Δf value reaches the required value.

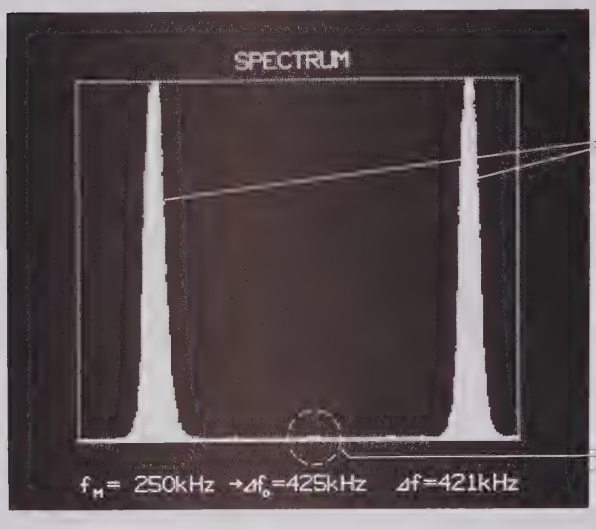


Figure 3-11b Suppressed IF carrier at a phase deviation η = 2.405 (Bessel null position)

If necessary, calibration can also be carried out at f_M = 92.593 kHz (or 83.3 kHz).

3.6.5 AUTOMATIC SWEEP WIDTH REDUCTION

The "automatic sweep width reduction" prevents, by suitable changing of the sweep voltage when the test frequencies are switched, the sidelines at both extremes of the swept IF carrier from extending outside the IF transmission bandwidth of the unit being measured. To understand this problem, it is necessary to consider the effect of the test signal $\hat{U}_A + U_M$ on a frequency modulator (see Figure 3-12). The carrier frequency of the frequency-modulated signal is swept over a sweep range $\pm\hat{\Delta}F$ in accordance with the modulator slope and the amplitude of the sweep voltage $\hat{U}_A$. The test voltage U_M generates a first pair of sidelines at an distance f_M from the swept carrier. If the sweep voltage is set accordingly, it is possible that with a given test frequency f_M, the upper and lower sideband lines in the extreme positions of the carrier $\pm\hat{\Delta}F$ are coincident with the limits of the transmission band of the unit being tested. At higher measuring frequencies with the same sweep voltage, each of the sidebands would lie outside the bandwidth to be examined at one end or the other of the sweep range and would be subject to unwanted variations. This would cause incorrect results, and these are avoided with the aid of the "automatic sweep width reduction". A circuit in the generator modifies the sweep voltage, when the test frequency is switched with the f_M pushbuttons [8], [9] to a higher value, such that a previously selected examination bandwidth is never exceeded; see Figure 3-12.

The "automatic sweep width reduction" is activated with switch [18] in the position "$\hat{\Delta}F_{RED}/\hat{U}_{A\ RED}$". The corresponding LED lights to indicate that the function is active.

Note: With the function "automatic sweep width reduction" active, the actual sweep width has the value

$$\hat{\Delta F}_{RED} = \hat{\Delta F} - f_M.$$

Whereas the sweep width (ΔF) is correctly indicated in the receiver, this factor must be taken into account when reading off the sweep width on the scale of [6].

The automatic reduction of the sweep voltage when the test frequency is switched from a lower to a higher value is also carried out when feeding external modulators with the test signal $\hat{U}_A + U_M$ (socket [14]). When setting the sweep voltage $\hat{U}_A$ with potentiometer [17], however, the slope of the external modulator must be taken into account in accordance with the equation

$$\hat{U}_A = \frac{\hat{\Delta F}}{S_{MOD}}$$

If, with "automatic sweep width reduction" active, a test frequency which exceeds the selected sweep width is selected, then the sweep voltage is switched off within the instrument. This status is signalled by the indicator C "$f_M > \hat{\Delta F}$". At the same time, the sweep width display on the RME-5 screen is erased.

The use of "automatic sweep width reduction" is recommended only in the measuring modes "$\Delta\tau$, $\Delta\varphi$" and "$\Delta U/U_0$".

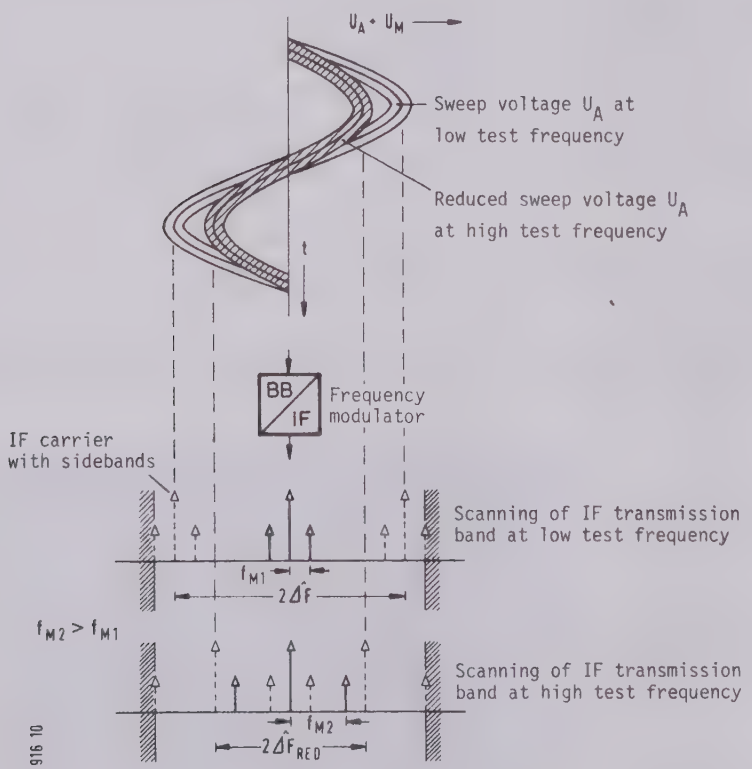


Figure 3-12 Behavior of the test signal $\hat{U}_A + U_M$ and the modulated IF signal when switched from low to high measuring frequency when in "automatic sweep width reduction"

3.6.6 IF CENTER FREQUENCY OFFSET

In cases where the unit being tested has a IF center frequency other than 70 MHz (or 35 MHz), the center frequency can be offset by ±25 MHz (or ±12.5 MHz) from its nominal value of 70 MHz (35 MHz)[1]. For this purpose, the rotary switch [4] on the RMS-5 must be set to the position "VARIAB" of the appropriate IF; the sweep width must be 0: Slide switch [7] in position "$\hat{\Delta}$F = 0".

Adjustment of the center frequency of the RMS-5, which is connected via socket [1] to [25] of the RME-5 (back to back mode), is carried out by turning potentiometer [3] (10-turn helical potentiometer, see Figure 3-13).

The "F_o" value is displayed with a resolution of 0.01 MHz on the screen of the RME-5, if this is set to the "frequency counter function" [4].

If the RME-5 is not installed locally (e.g. for end to end measurement), and no separate frequency counter can be connected to socket [31] (0.01 x IF), then the frequency setting is carried out by means of the scales on potentiometer [3]. The resolution is ≤ 50 kHz/≤ 25 kHz, depending on the selected IF.

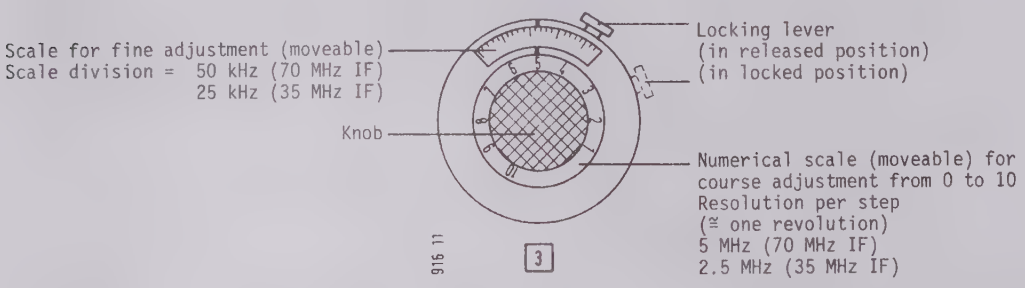

Scale for fine adjustment (moveable)
Scale division = 50 kHz (70 MHz IF)
25 kHz (35 MHz IF)
Knob
Locking lever
(in released position)
(in locked position)
Numerical scale (moveable) for course adjustment from 0 to 10
Resolution per step
(≙ one revolution)
5 MHz (70 MHz IF)
2.5 MHz (35 MHz IF)
916 11
3

Figure 3-13 Potentiometer [3] for offsetting IF center frequency of the RMS-5

Note: If the IF center frequency is offset, the sum of the selected center frequency and the sweep width must not exceed the extreme values of 45 and 95 MHz (or 22.5 and 47.5 MHz) in the IF range.

3.6.7 PHASE CORRECTION OF DEFLECTION VOLTAGE U_x

3.6.7.1 IF sweep measurements "U_x (IF)"

In the case of IF measurements, the deflection voltage U_x for display of the sweep curve on the screen is recovered automatically with the correct phase from the IF signal at input P_I [25].

---

1) If the IF center frequency is offset to a value other than 70 or 35 MHz, interference lines may occur in the distortion results - particularly at sweep widths of a few MHz - these resulting from higher order mixing products. They are the price for the relatively large signal level at the participating mixers and thus for the good noise characteristics of the RM-5. As these lines are easily detected and do not falsify the results, this compromise was chosen rather than the alternative of "high noise, no interference lines".

After switching of the sweep frequency, at extreme ambient temperatures, or due to aging of components, fine correction of the deflection voltage phase for IF sweep measurements may nevertheless be necessary.

The pushbutton function "U_X (IF)" below [18] indicates any necessary correction. To display the forward and backward sweep of the sweep curve, depress pushbutton [17] (LED on). If two sweep measurement results [2] and [10] were displayed when this is done, the result which was called up with pushbutton row [10] disappears from the screen.

For phase correction of a result selected with the lower row of pushbuttons [10] (e.g. $\Delta U/U_0$), the result selected with pushbuttons [2] should if necessary be switched off with the corresponding "ON/OFF" pushbutton.

Phase correction is carried out with the arrow pushbuttons [18] until the forward and backward sweeps coincide. The correction range for the phase is $\pm 6°$. After this, switch off the return sweep of the curve with pushbutton [17]; the second sweep result, if selected, is again displayed.

3.6.7.2 BB sweep measurements "U_X (BB)"

For BB distortion measurements, the phase of U_X must always be checked, as this may have changed with respect to the test signal - influencend by the unit being tested - see Figure 3-14. This status is indicated when pushbutton functions [23] "BB measurement" and [18] "U_X (BB)" are active simultaneously. The phase deviation may lie between 0 and $\pm 180°$. Correction is carried out as described for correction of U_X (IF). Major corrections can be carried out by holding down the arrow pushbuttons under [18] (see Figure 3-14a), while fine corrections are executed by momentarily depressing the pushbuttons (see Figure 3-14b); adjust until the forward and backward sweeps coincide. The possible 180° phase uncertainty can be removed by means of the blanking gap described in section 3.6.8.

There are also FM demodulators which have a high-pass characteristic and thus prevent transfer of the low frequency sweep signal. In this case, recovery of the deflection voltage from the BB signal is not possible. As a replacement, an IF signal from an IF access point before the demodulator input can be connected to the P_I input [25], and the deflection signal derived from this.

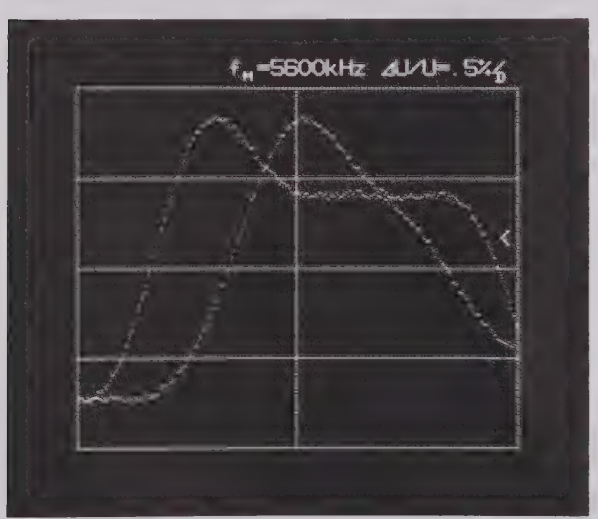


Fig. 3-14a Typical shape of "forward and backward sweep" for BB measurement

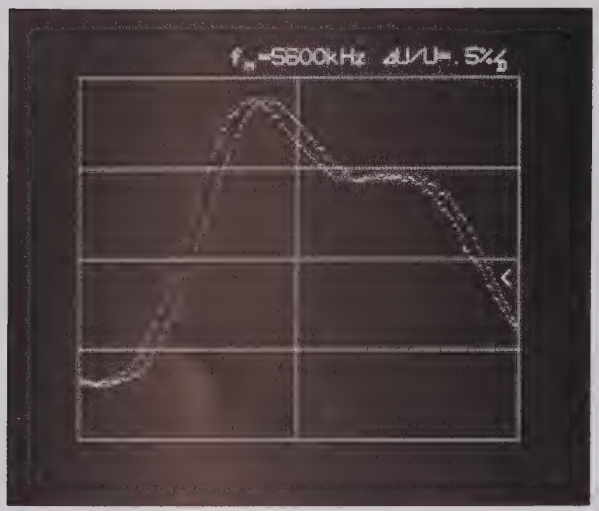


Figure 3-14b Phase correction of the BB curve shown in 3-14a, only slight deviation remains

For this purpose, the pushbutton "U_x (IF)" under [18] must be depressed. Correction of the deflection signal is carried out as described previously with the arrow pushbuttons under [18].

For BB distortion measurements, pushbutton [23] with the note "PHASE U_x" and pushbutton "U_x (BB)" [18] active always means that the phase of U_x must be checked and corrected if necessary.

3.6.8 BLANKING GAP

Due to the sinusoidal shape of the deflection signal, there is always a 180° phase uncertainty in the displayed result for BB distortion measurements.

This can be removed by inserting a blanking gap in the measuring curve by depressing pushbutton [11] on the RMS-5. The gap is displayed most clearly on the screen in the result $\Delta U/U_o$ and should - positive modulation is a prerequisite - be moved to the left edge of the screen with the arrow pushbuttons below [18] of the RME-5; see Figure 3-15.

As this gap is only a coarse indication for phase adjustment at the deflection voltage, phase adjustment should then be completed by depressing pushbutton [17] and the arrow pushbuttons [18] to obtain coincidence of the forward and backward sweeps.

The polarity of modulators and demodulators can also be determined with the aid of the sweep gap.

Figure 3-15 Insertion of a blanking gap for avoiding 180° phase uncertainty (sweep measurement result according to Figure 3-14)

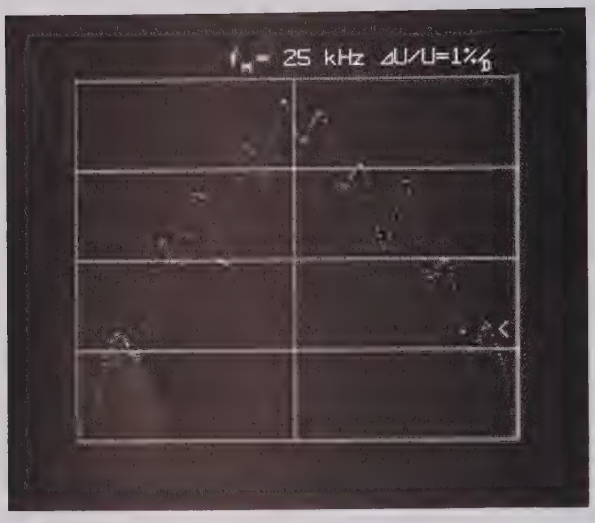
3.6.9 300 Hz BANDWIDTH

For evaluation of results, the bandwidth of the RME-5 can be reduced to 300 Hz by pressing pushbutton [7] (LED on).

Selection of the correct bandwidth depends on the shape of the measured result. For distortion measurements, for example with a high harmonic content, the 300 Hz filter should be switched off (LED off). The rule of thumb is: The number of harmonics on the measured curve should be less than the ratio of the selected bandwidth to twice the sweep frequency f_A. The same applies to IF frequency response measurements of level and return loss with steeply slopingfrequency responses, as the rapid rate of change of the frequency could otherwise falsify the result.

Typical applications of the 300 Hz filters are:

- Noisy curves at the low sweep frequency (f_A = 18 Hz), such as can occur in satellite transmissions; "Noise suppression".
- Distortion curves with a ripple characteristic, where only the linear or quadratic component is interesting for evaluation, as shown in the example in Figure 3-16a, b.



300 Hz filter off

300 Hz filter on

Figure 3-16 Effect of the 300 Hz filter on a distortion curve with ripple characteristic, sweep frequency f_A = 70 Hz

3.6.10 IF FREQUENCY RESPONSE CORRECTION ΔP_I

For ΔP_I measurements, it is possible to eliminate undesirable linear slope frequency responses, such as those caused by the connecting cables of IF assemblies; see Figure 3-17.

First, a ΔP_I measurement is carried out in the appropriate frequency range without the unit to be tested; the RMS-5 and RME-5 are connected back-to-back with the cables to be used for subsequent testing. The frequency response of the cables is then indicated as a sloping straight line on the screen in the most sensitive measuring range (0.1 dB/DIV).

Now depress pushbutton [19] "ΔP_I frequency response correction" - red LED on. With a suitable screwdriver, turn the trimmer potentiometer to the right of pushbutton [19] until the line on the screen is horizontal - this compensates for the frequency response of the cables.

With "frequency response correction" still active, the ΔP_I measurement is now carried out through the IF assembly. The frequency response of the ΔP_I curve is now determined only by the unit being tested.

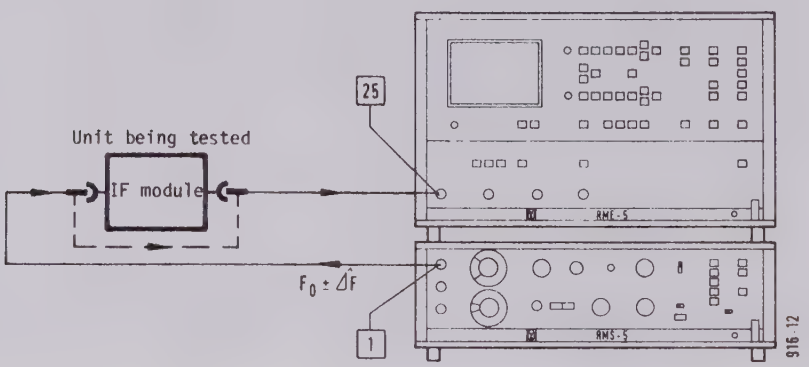


Figure 3-17 Effects of connecting cables on ΔP_I frequency response measurement

3.7 INTERNAL EVALUATION OF SWEEP MEASUREMENT RESULTS

3.7.1 NOISE AVERAGING [5]

If noise is superimposed on the sweep measurement result, which is particularly common on satellite links (f_A = 18 Hz), the noise can be suppressed to a great degree by "averaging". Calculation of the average value is carried out from the current measurement result Y_i and an average value $\overline{Y}_{i-1}$ stored during the preceding sweep cycle. The new average value $\overline{Y}_i$ is displayed on the screen, just as the average $\overline{Y}_{i-1}$ was displayed in the preceding cycle. 256 average values are calculated per sweep cycle for display of a curve; see Section 4.3.

This method permits detection and evaluation of the structure of sweep curves including a large amount of noise. The amount of noise averaging can be determined by suitable selection of the averaging factors N: 2, 4, 8, 16, 32.

Averaging is first activated by depressing the "⇧" pushbutton under [5] once: Averaging factor N = 2 (corresponding LED on) is active. Further depression of the "⇧" pushbutton increases the noise averaging by one stage, this being indicated by the appropriate LED. Maximum noise suppression is achieved at N = 32. Figure 3-18 shows the effects of the averaging factors - increasing the factor provides a smoother curve. Two distortion measurement results "$\Delta\tau$" and "$\Delta U/U_o$" are displayed simultaneously.

Noise averaging can be reduced step by step with the "⇩" pushbutton [5]; if averaging factor 2 had been selected, depression of this pushbutton switches off the averaging function and all LEDs are then off.

Figure 3-18a Noisy sweep measurement results $\Delta\tau$ and $\Delta U/U_o$; noise peaks: ►

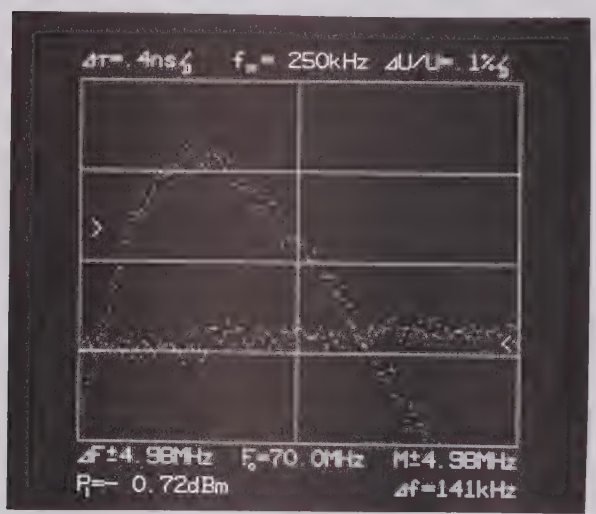


Figure 3-18b Sweep measurement results as in a), but averaging factor N = 2

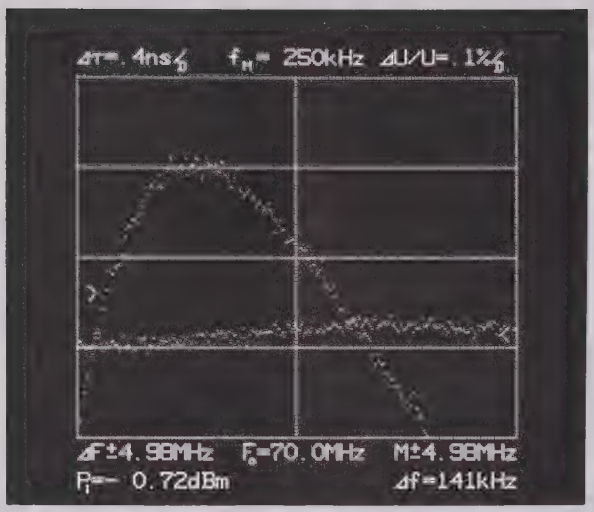


Figure 3-18c Sweep measurement results as in a), but averaging factor N = 8

Note: Before switching on the noise suppression function [5], the noisy curve should be adjusted on the screen(vertical position, measuring range) such that the noise peaks still lie within the digitalization range (screen display) in order to avoid errors in averaging.

Vertical positioning of the sweep curves with potentiometers [1] or [9] with "noise averaging" active should not be carried out suddenly due to the delayed effect (particularly if N = 32 is active). If necessary, the averaging should be reduced or switched off.

3.7.2 CURVE DIFFERENCE [12]

In order to eliminate intrinsic distortions of the measuring configuration from the total result, or to adjust a unit being tested to a specified curve, a reference curve "REF" can be stored with the "normalizer" function of pushbutton row [12] and this can then be subtracted from the actual curve "A": "DIFF" = "A"-"REF".

The reference curve, a distortion measurement result selected with [2] or [10], is stored by depressing the pushbutton "STORE/REF"; see the example in Figure 3-19a. Transfer of the "REF" curve into the memory is signalled by momentary illumination of the LED above "STORE/REF".

After the unit to be tested has been connected into the test configuration, the actual curve "A" appears on the screen (see example in Figure 3-19b). Depression of pushbutton "DISPL" (LED "DIFF" on) causes the difference curve to be displayed and to be identified by the note "DIFF" (= "A"-"REF") on the bottom line of the screen; see Figure 3-19c. Any adjustments made to the unit being tested (curve "A") are immediately visible in the difference curve "DIFF", which is very advantageous for alignment work.

The reference curve can be displayed by again depressing the "DISPL" pushbutton, the note "REF." appearing in the bottom line of the screen. This permits reliable identification of the three participating curves for logging of results by serial printing (video printer).

Depression of pushbutton "OFF" causes the actual sweep curve to be displayed. The LEDs above the "DISP" pushbutton are off. If a new reference curve is stored with the "STORE/REF" pushbutton, the old reference curve is updated.

Note: When setting up the reference curve - range and vertical position - ensure that the upper and lower horizontal grid lines are not exceeded.

If the maximum ranges are exceeded, it is no longer possible to determine the "DIFF" function values (digitalization range exceeded); the "DIFF" curve will not be recorded at this position.

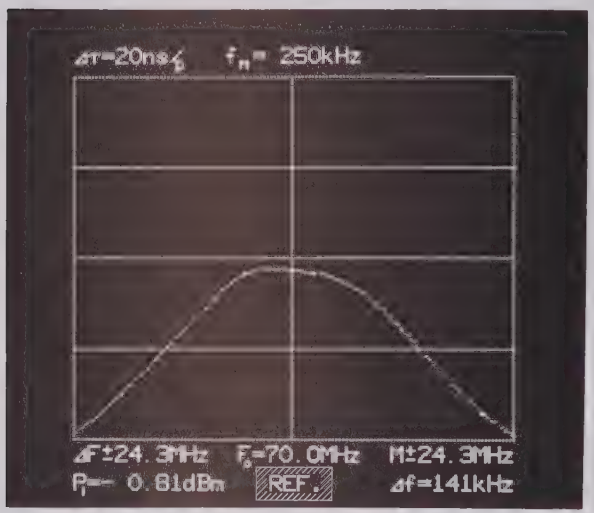


Figure 3-19a NORMALIZER function using example of $\Delta\tau$ distortion result, reference curve "REF"

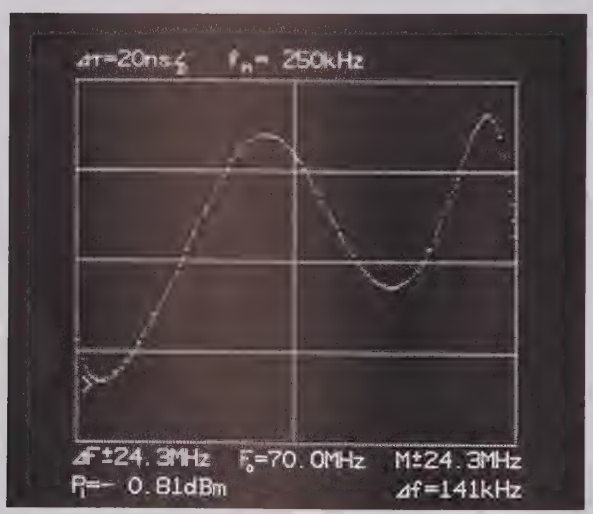


Figure 3-19b NORMALIZER function using example of $\Delta\tau$ distortion result, current sweep curve "A"

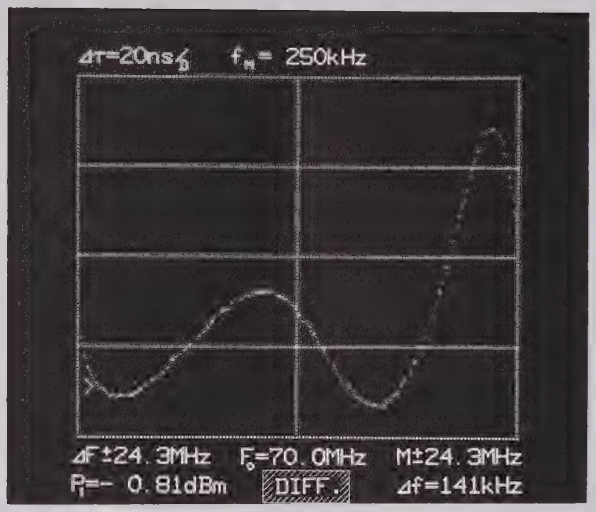


Figure 3-19c NORMALIZER function using example of $\Delta\tau$ distortion result, difference curve "DIFF" = "A"-"REF"

3.7.3 CURVE ANALYSIS "LIN"/"PARAB" [20]

In the case of distortion measurement results $\Delta\tau$, $\Delta\varphi$ and $\Delta U/U_0$, in addition to the absolute distance between the maximum and minimum value of the curve, the curve shape composition from linear and parabolic components is often interesting, as most sweep curves which occur practically are determined by these two components.

The microprocessor solves this task by comparing the two end points of the curve (P_0, P_2) - see Figure 3-20a -, i.e. calculates the difference in the y direction. This value is displayed as the linear component "LIN" (sloping) on the screen. It also determines the difference between the secant connecting the two end points and the curve itself (P_1) at the center of the screen (i.e. at center frequency F_0). This "PARAB" (curving) component is also displayed with the correct scale on the screen, see Figure 3-20b. As calculation is carried out continuously, the numerical values can be used directly as alignment criteria for distortion adjustment.

Activation of "LIN"/"PARAB": Depress pushbutton "LIN/PARAB", LED on.

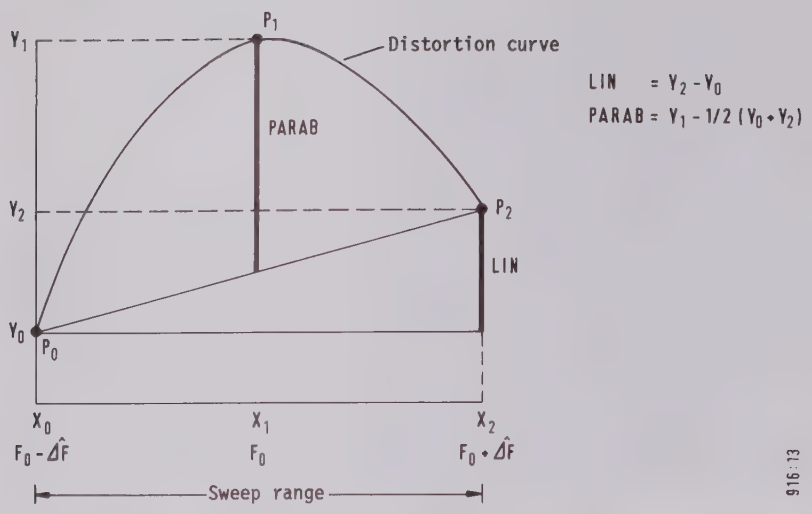


Figure 3-20a Definition of sloping "LIN" and curving "PARAB" components

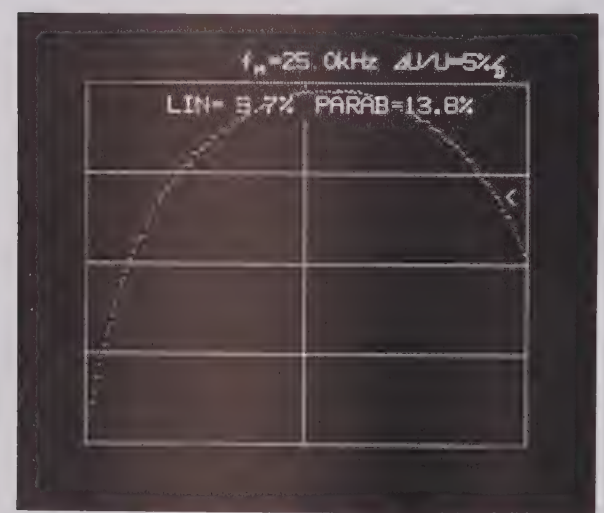


Figure 3-20b Monitor display of curve analysis

3.8 APPLICATION SECTORS OF THE MEASURING SETUP RM-5

The description of the application sectors is based primarily on the requirements resulting from practical operations. For this reason, the various measuring modes are not described with respect to the measuring setup, but are treated on the basis of the object being measured. This procedure means that some of the possible measuring modes are referred to several times. However, a detailed description of a measuring mode is provided only in the section in which it is first mentioned. Subsequent repetitions deal only with new aspects; otherwise, the reader is referred to the section with the detailed description.

Applications of the Measuring Setup RM-5 can be divided into three general sectors:

- Operation measurements on operating radio-link systems, carried out by system manufacturers or PTT or private operating companies during commissioning and subsequently during maintenance.

- Measurements on single assemblies of the radio-link or satellite system in laboratories or testing departments of system manufacturers.
- Measurements on satellite systems

The facilities offered by the Measuring Setup RM-5 make it possible to carry out measurements either at BB level or IF level, or between the two levels. The intermediate frequency of the unit being measured can be 70 MHz (or 35 MHz); other values within the frequency range of the RM-5 are possible if the IF center frequency offset function is utilized.

3.8.1 END TO END MEASUREMENTS ON RADIO-LINKS (BB-BB)

Terminal stations of radio-links are the ends of a modulation section, which consists of several radio-links and relay stations. The baseband (BB) signal supplied by the FDM multiplex device is converted in the radio-link terminal station into a frequency modulated IF signal. For transmission via a radio-link antenna, further conversion to the radio frequency (RF) level is necessary. At the opposite end, the signal is converted back to the BB level.

The most important measurements which are carried out between radio-link terminal stations are:

- Measurement of group delay and linear distortion $\Delta\tau$ and $\Delta U/U_0$ (measuring frequencies $f_M < 1$ MHz),
- Measurement of differential phase and gain $\Delta\varphi$ and $\Delta U/U_0$ (measuring frequencies ≥ 1 MHz).

3.8.1.1 Distortion measurements $\Delta\tau$, $\Delta\varphi$, and $\Delta U/U_0$

Measuring configuration:

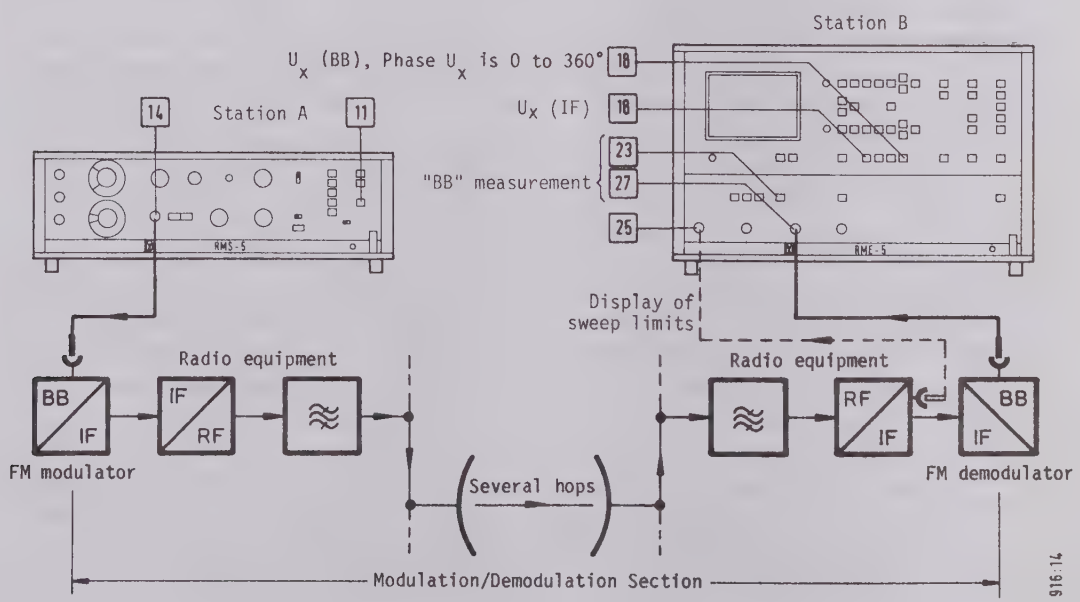


Figure 3-21 Distortion measurements between radio-link terminal stations (BB-BB)

On the RMS-5 Generator of station A, the measuring voltage (potentiometer [16]) and the sweep voltage (potentiometer [17]) must be set up.

Generally, precise measuring specifications exist for measurement on radio links, and these show the setting values for the system being used. This is the only method of ensuring that results are comparable.

If no measuring specifications exist, there are two possibilities for setting up:

- Station A has an RME-5 Receiver: The RME-5 Receiver is connected to the IF measuring socket at the system modulator output, permitting display of the sweep width on the screen. The sweep width on the RMS-5 should then be set up as shown in table 3-3 at the lowest measuring frequency or with "automatic sweep width reduction" switched off.
- Station A has no RME-5 Receiver; test configuration as shown in Figure 3-21: The sweep voltage U_A to be set up can be calculated with the following formula:

$$U_A = \frac{\hat{\Delta F}}{\Delta f_N} \times 274\ mV \times 10^{(p_Q' + a_p)/20}$$

Where:

$\hat{\Delta F}$ = Peak value of IF sweep width (= IF transmission band).

Δf_n = r.m.s. value channel frequency deviation at neutral frequency f_n.

p_Q' = Power level at modulator input Q', which causes an r.m.s. channel frequency deviation Δf_n; in an 1800 channel system, for example, a level of -40 dBm at point Q' with the relative level -40 dBr results in an r.m.s. deviation Δf_n of 140 kHz at the neutral frequency f_n = 4988 kHz.

a_p = Preemphasis attenuation at sweep frequency f_A; in the case of preemphasis networks for voice grade channels, a_p = 4 dB.

Table 3-3 shows typical, practical values for $\hat{U}_A$.

The magnitude of the test voltage depends generally on the r.m.s. channel frequency deviation Δf. A satisfactory result is achieved if - starting at a small value - the test voltage is increased until the result no longer appears noisy. If the test voltage is too large, the fine structure of the result will be lost.

Radio-link system	Relative level at point Q'	p_Q'	Δf_n	$\hat{\Delta F}$	$\hat{U}_A$
960 channels	-48 dBr	-48 dBm	200 kHz	±12 MHz	0.104 V
1800 channels	-40 dBr	-40 dBm	140 kHz	±12 MHz	0.372 V

Table 3-3a Value table for determining the sweep voltage $\hat{U}_A$ for two common radio-link systems

Evaluation of the results at station B is carried out either on the monitor of the RME-5 (simultaneous display of $\Delta U/U_o$ and $\Delta\tau$ or $\Delta\varphi$!) or externally by a computer (IEC Bus). The results can be logged with the aid of a video printer or XY plotter.

If the dotted connection in Figure 3-21 is inserted between the decoupled IF access point before the demodulator input in station B and the P_I input [25] on the RME-5, then the sweep width ΔF and the IF level P_I together with the frequency markers M can be added to the result display on the screen (see Figure 3-6) if pushbutton "U_x (IF)" [18] is pressed; the LED above the BB

pushbutton [23] continues to light to indicate that this is nevertheless a BB measurement.

Another case where the auxiliary IF signal has to be connected is where the system demodulator blocks the sweep frequency required for recovery of the deflection voltage U_x. In this case, depress pushbutton "U_x (IF)" [18] (LED on) and correct the phase of the deflection signal - pushbutton function [17] on - with the arrow pushbuttons under [18], using the gap pulse [11] in the RMS-5 to remove the 180° phase uncertainty (see section 3.6.8).

3.8.2 END TO END MEASUREMENTS BETWEEN REPEATER STATIONS (IF-IF)

In order to localize faults, it is important to split the measurement at the BB level over a complete modulation section into several partial measurements. Measurements via one radio-link from repeater station to repeater station are particularly important in this respect.

In a repeater station, only the IF ports are generally accessible, i.e. the measuring signal passes from the IF input of the radio-link equipment on the transmitting side to the IF output of the receiver in the next repeater station.

The RMS-5 Generator provides a swept and frequency-modulated IF signal as a measuring signal, this being evaluated in the RME-5 Receiver as required. The various measuring tasks are described in the following sections.

3.8.2.1 Distortion measurements $\Delta\tau$, $\Delta\varphi$ and $\Delta U/U_0$

Measuring configuration:

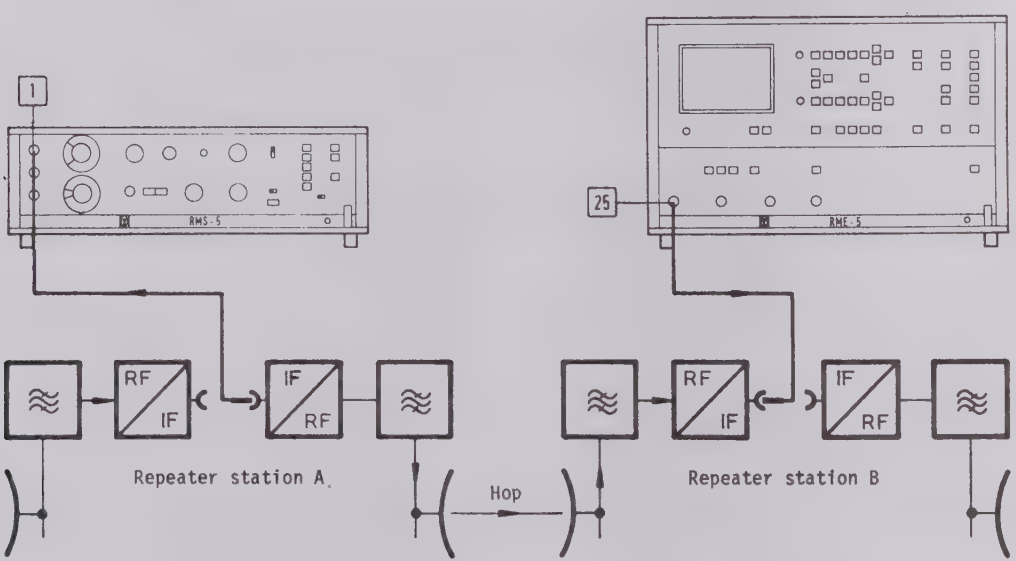


Figure 3-22 Distortion measurements between repeater stations (IF-IF)

Settings on the RMS-5 Generator:

[2], [13] : Nominal system value for U_{IF} = 300 mV ≙ 0.8 dBm
[4] : Center frequency 70 MHz (35 MHz)
[18] : Automatic sweep width reduction; on
[16] : Measuring deviation Δf equal to r.m.s. channel frequency deviation as specified for the system, or gradually increase test deviation until the result on the RME-5 no longer appears noisy (limit: disappearance of fine structure of result)
[6] : Sweep width $\hat{\Delta F}$ according to system
[8], [9] : Measuring frequencies as required
[19] : Sweep frequency as required

Pushbutton functions on the RME-5 Receiver:

[22] : "IF" measurement
[21] : IF as set on RMS-5

Evaluation of the results is carried out on the screen of the RME-5 (simultaneous display of $\Delta U/U_0$ and $\Delta\tau$ or $\Delta\varphi$!) or by an external computer via the IEC Bus.

Note: It is also possible to return the distortion measurement results to the transmitting repeater station (see Section 3.8.3).

3.8.2.2 IF frequency response ΔP_I

With the measuring configuration for distortion measurements shown in Figure 3-22, it is also possible to measure the amplitude frequency response of the IF carrier, which is swept through the IF transmission range, providing there are no limiters which flatten the frequency response of the system.

In order to ensure that the sweep signal $\hat{U}_A$ covers the whole IF transmission range, it is necessary either to switch off the "automatic sweep width reduction" or to use the lowest test frequency. Except for the pushbutton function "ΔP_I" under [2] or [10], all other settings are the same as described in Section 3.8.2.1 for distortion measurement.

For evaluation of the results, remember that frequency response correction can be carried out as described in Section 3.6.10.

3.8.2.3 IF level and r.m.s value deviation

During measurements in accordance with Sections 3.8.2.1 and 3.8.2.2, the level and r.m.s. value deviation of the IF signal can be measured with pushbutton function [4] "IF counter" in order to check the settings. The result is displayed on the screen as shown in Figure 3-9.

In order to achieve the full accuracy of the IF level and deviation meter, calibration should be carried out as described in Section 3.6.4.

3.8.3 RETURNING DISTORTION MEASUREMENT RESULTS TO THE TRANSMITTING STATION DURING END TO END MEASUREMENTS (IF-IF)

If end to end measurements are carried out at the IF level, it is possible to return the distortion measurement results $\Delta\tau$, $\Delta\varphi$ and $\Delta U/U_0$ from the receiving station (B) to the transmitting station (A). A complete Measuring Setup must be installed at both stations. The configuration is shown in Figure 3-23.

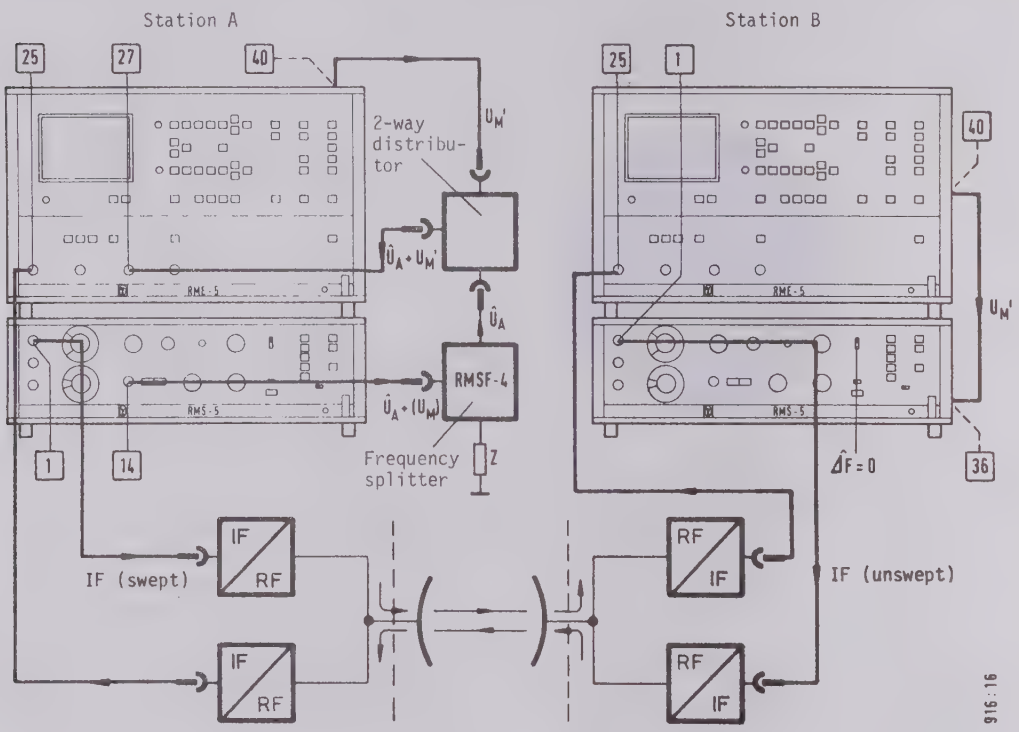


Figure 3-23 Transmitting distortion measurement results from Station B to Station A

The RME-5 at station B after demodulation, passes the received IF signal, via the demodulator output [40] (the distorted test signal U'_M) to input [36] (U_{MEXT}) of the RMS-5 in the same station. The test signal U'_M is frequency-modulated in the RMS-5 but not swept. The unswept IF signal is transmitted back to station A and connected to the IF input [25] (P_I) of the RME-5. The test signal U'_M available at the demodulator output [40], which was not distorted further during transmission ($\Delta\hat{F} = 0$), is connected together with the sweep voltage $\hat{U}_A$ derived from the RMS-5 (station A) to the BB input [27] of the RME-5, which operates in BB mode - pushbutton [23] depressed.

3.8.4 MEASUREMENTS ON MODULATORS (BB-IF)

The separate measurement of modulators and demodulators in testing departments is necessary in order to permit compensation for any non-linear characteristics.

3.8.4.1 Setting the IF center frequency

For setting the IF center frequency of modulators, the RME-5 is used as an "IF counter" - push-button [4] depressed, with resolution of 0.01 MHz for the value "F_o". Figure 3-24 shows the measuring configuration.

Settings on the RME-5:

[22] : IF measurement
[21] : IF center frequency
[4] : IF counter

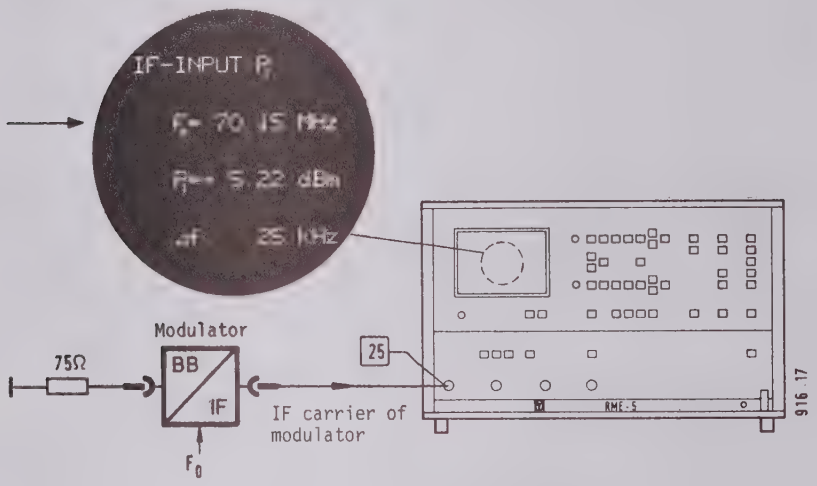


Figure 3-24 Setting the modulator center frequency "F_o"

The unit being tested is adjusted to the required F_o value, which is displayed direct for reading as "IF-INPUT P_I" on the screen.

3.8.4.2 Adjusting the modulator slope "S_{Mod}"

The slope S_{Mod} of a modulator is defined as

$$S_{Mod} = \Delta f / U_M$$

where Δf is the r.m.s. value frequency deviation and U_M is the RMS value of the modulation voltage, i.e. RMS value of the test voltage.

In the case of frequency modulation with one sinusoidal signal, the IF carrier disappears from the spectrum of the frequency-modulated signal at a modulation index $\eta = 2.405$ (first null position of the Bessel function). As the modulation index η is

$$\eta = \hat{\Delta f} / f_M$$

with peak deviation $\hat{\Delta f}$ and modulation frequency f_M (or test frequency), the r.m.s. value deviation at the modulation index $\eta = 2.405$ is

$$\Delta f = 2.405 \times f_M / \sqrt{2}$$

As a specific slope is required for the modulator and as the modulation frequency f_M can be set on the RMS-5, the modulation voltage U_M which is necessary for generation of the first Bessel null position can be calculated:

$$U_M = \frac{2.405 \cdot f_M}{\sqrt{2} \cdot S_{Mod}}$$

Example: The slope of a modulator is to be 10 MHz/V; $f_M = 277.\overline{7}$ kHz

$$U_M = U_{Mod} = \frac{2.405}{\sqrt{2}} \cdot \frac{0.278 \text{ MHz}}{10 \text{ MHz/V}} = 47.28 \text{ mV} \cong -15.25 \text{ dBm}$$

This calculated level can be set with potentiometer [16] of the RMS-5, using the "BB level meter" function of the RME-5 or with a separate level meter of the appropriate accuracy.

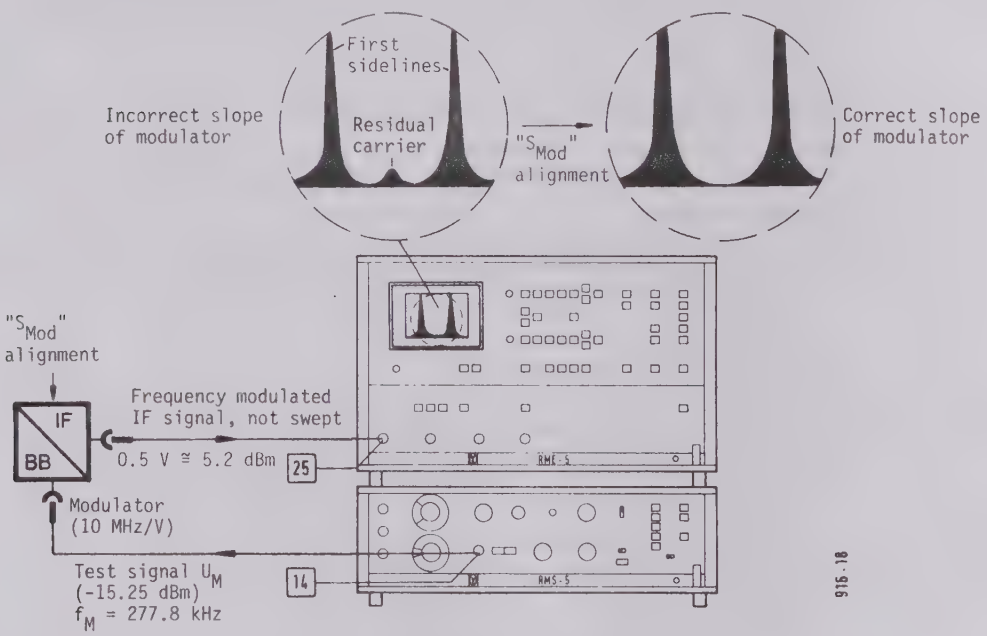


Figure 3-25 Setting modulator slope with the Bessel method

After this, set up the measuring configuration shown in Figure 3-25. The RME-5, which acts as a spectrum analyzer, displays only the sidelines of the IF signal on the monitor; if the slope S_{Mod} of the unit being tested is correct.

If the IF carrier appears in the frequency spectrum, which means that $S_{Mod} \neq 10$ MHz/V, then the unit being tested should be adjusted until the modulator slope is correct.

If the modulator input is preceded by a preemphasis network, which is the case on modulators used in radio-link systems, the above considerations are true only if the attenuation of the preemphasis network at f_M is taken into account. The modulation voltage must be increased by the value of this attenuation.

Settings on the RMS-5 Generator:

[16] : U_M calculated in accordance with the above formula and set with the aid of a precise level meter at output [14]

[17] : $\hat{U}_A = 0$

[8] : Pushbutton function "0.277 ∇ " or "0.093 ∇ " (or "0.250 ∇ " or "0.083 ∇ ")

Settings on the RME-5 Receiver:

[22] : IF measurement

[21] : IF according to IF of unit being tested

[3] : "BESSEL SPECT. ∇ "

Note: Adjustment of the modulator slope is basically possible at other measuring frequencies of the RMS-5and depends only on whether the maximum possible modulation voltage U_M of the RMS-5is sufficient for generation of the first Bessel null position for a given modulator slope.

Instead of the RMS-5, a level generator can be used, its output signal being connected directly to the BB input of the modulator being tested. This makes it possible to use test frequencies which are not available in the test frequency series of the RMS-5 (e.g. neutral frequency).

In both cases, care must be taken that the peak deviations at a given test frequency do not become larger than the IF transmission band of the modulator.

3.8.4.3 Distortion measurements $\Delta\tau$, $\Delta\varphi$ and $\Delta U/U_0$

For distortion measurements on modulators, the RMS-5 Generator supplies a sum signal consisting of the sweep voltage and test voltage. The sweep voltage $\hat{U}_A$ determines the sweep width of the IF signal measured at the output of the unit being tested.

Settings on the RME-5:

[22] : IF

[21] : IF corresponding to IF of unit being tested

[2], [10] : Measured parameters $\Delta\tau$, $\Delta\varphi$ and $\Delta U/U_0$

The sweep width $\hat{\Delta F}$ for exploring the IF transmission band is set up with the aid of the ΔF value displayed on the RME-5, by potentiometer [17] of the RMS-5, with "automatic sweep width reduction" switched off and at the lowest measuring frequency. The values for setting must be selected according to the system.

The test voltage U_M must be set such that the displayed result is as free of noise as possible, without losing the fine structure of the result (approx. value = 1...2 x channel frequency deviation).

The evaluation of the results is carried out on the screen of the RME-5 or externally by a computer connected via the IEC Bus.

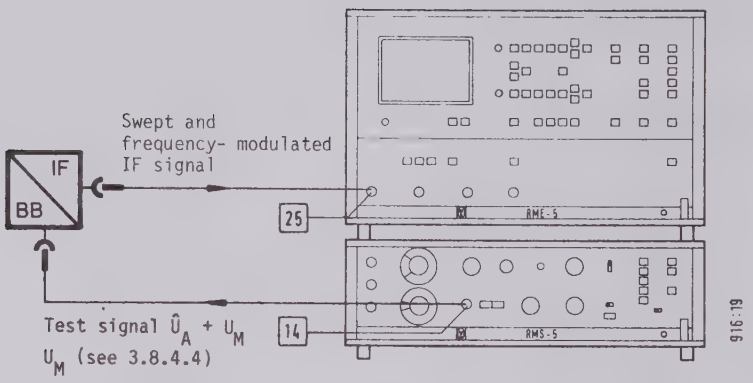


Figure 3-26 Distortion measurements on a modulator

3.8.4.4 Determining the temperature response of the IF center frequency of modulators

Determination of the temperature variation response of the IF center frequency of modulators is an interesting measurement in development laboratories and testing departments. This can be carried out easily with the "frequency counter function" of the RME-5 (pushbutton [4] depressed). The measuring configuration is the same as that shown in Figure 3-26. Display of the temperature caused drift of the center frequency can be carried out between recording of distortion results; see also Section 3.8.4.3. Switch [7] of the RMS-5 is set to position "$\hat{U}_A$ = 0" and the unswept FM spectrum is present at the input of the IF level meter if pushbutton [4] of the RME-5 is depressed. Center frequency deviation greater than 10 kHz are recorded and the current absolute value "F_o" is displayed numerically on the screen (monitor display "IF-INPUT P_I"). The temperature variation response of the modulator center frequency can thus be determined by observing the "F_o" value at suitable intervals.

In order to return to the original display of distortion results, return switch [7] (RMS-5) to its original position ($\hat{\Delta}F$ or $\hat{\Delta}F/10$) and select the appropriate distortion value with [2] ([10]). The sweep width now also returns to its original value, as the potentiometer [17] was not moved in the meantime.

3.8.4.5 IF frequency response ΔP_I

The measuring configuration is as shown in Figure 3-25:
Execution of measurement and evaluation of the results is carried out as described in Section 3.8.2.2.

3.8.4.6 IF level and r.m.s. value frequency deviation

The test measuring configuration is as shown in Figure 3-25
Execution of measurement and evaluation of the results is carried out as described in Section 3.8.2.3.

3.8.5 MEASUREMENTS ON DEMODULATORS (IF-BB)

3.8.5.1 Adjusting the demodulator slope

The slope S of a demodulator is defined as

$$S_{Demod} = U/\Delta f$$

With $\Delta f = 2.405 \times f_M / \sqrt{2}$ ($\eta = 2.405$: first Bessel null position, see also Section 3.8.4.2), the voltage at the output of the demodulator becomes

$$U_{Demod} = \frac{2.405 \times f_M}{\sqrt{2}} \times S_{Demod}$$

If the demodulator slope is known, and with a measuring frequency f_M set up on the RMS-5, a specific voltage U_{Demod} appears at the output of the demodulator and can be measured with the BB level meter.

Settings on the RMS-5 Generator:

[2], [13] : +0.8 dBm (≙ IF input level for demodulators)
[4] : Center frequency 70 MHz (35 MHz)
[16] : U_M = 0 V
[7] : ΔF = 0
[8] : Pushbutton function "0.277▽" (or "0.250▽")

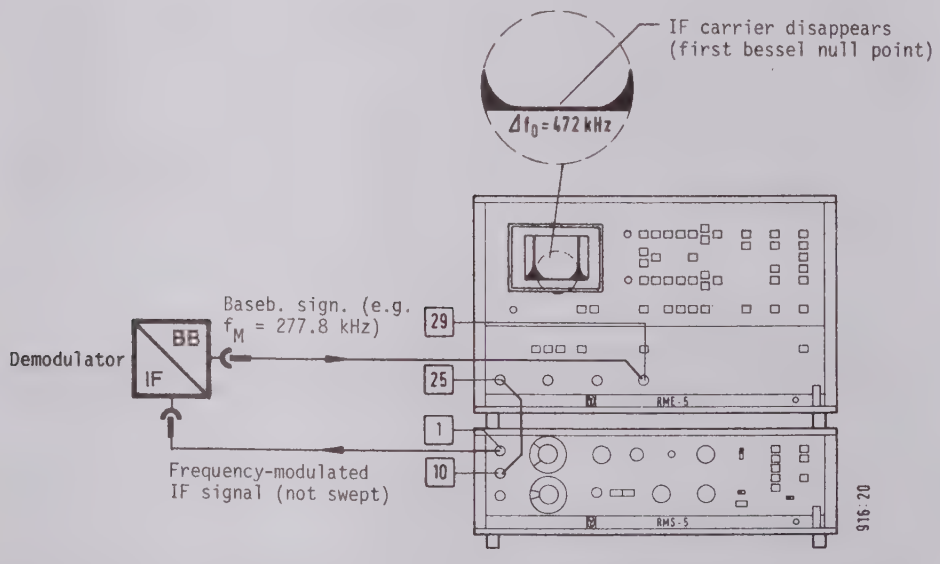


Figure 3-27 Adjusting demodulator slope

Settings on the RME-5 receiver:

[22] : IF
[21] : IF corresponding to IF of unit being tested
[3] : "BESSEL SPECT. ▽"

Adjustment of the demodulator slope is carried out in two steps:

First step: With a cable connected between socket [10] of the RMS-5 and P_I socket [25] of the RME-5, and at a test frequency f_M = 277.77 or 250 kHz, increase the test voltage U_M until the first Bessel null position is displayed on the RME-5, used as a spectrum analyzer.

Note: It is also possible to generate the first Bessel null position in the same manner with f_M = 92.59 or 83.3 kHz. For measuring frequencies higher than 277.77 or 250 kHz, the effective deviation Δf which can be generated in the RMS-5 is not sufficient to generate a bessel zero point.

Second step: At the same time, the IF signal from socket [1] of the RMS-5 with the Δf setting is carried out in step one - see Δf value in screen display below the IF spectrum - to the IF input of the unit being tested. The demodulated signal is measured by the built-in BB level meter, socket [29]; see Section 3.5.4. If the level deviates from the expected value, the slope of the unit being tested should be corrected with the appropriate adjustment components.

If the demodulator output is followed by a deemphasisnetwork, then the attenuation of this network at the measuring frequency f_M must be taken into account. The level meter indicates a voltage equal to the actual output voltage minus the deemphasis attenuation.

3.8.5.2 Distortion measurements $\Delta\tau$, $\Delta\varphi$ and $\Delta U/U_0$

The RMS-5 Generator provides a frequency-modulated and swept IF signal. Adjustments to the sweep width and test deviation carried out with potentiometers [6] and [16] can be followed direct on the screen display; pushbutton "U_x (IF)" depressed.

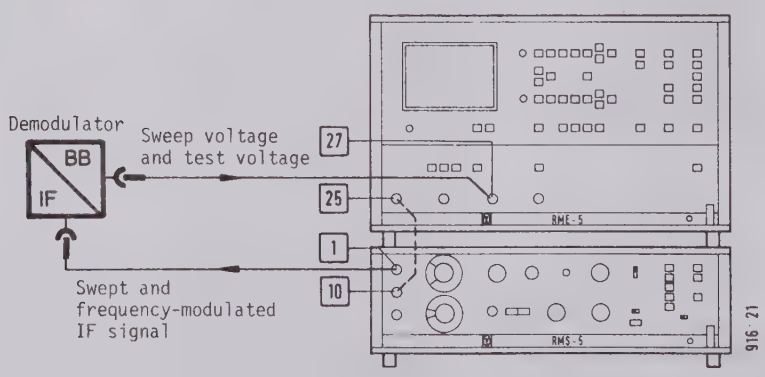


Figure 3-28 Distortion measurements on a demodulator

Settings on the RMS-5 Generator:

[2], [13] : Nominal value for U_{IF} = 300 mV ≅ +0.8 dBm

[4] : IF center frequency 70 MHz (35 MHz)

[16] : Test deviation Δf equal to r.m.s. value channel frequency deviation, selected according to system. In order to reduce noise on the result, the test deviation can be increased, providing that the fine structure of the result is not lost.

[6], [7] : Sweep width $\hat{\Delta F}$ according to system

[8], [9] : Pushbutton function "test frequency f_M" as required

[19] : Sweep frequency as required

Settings on the RME-5 receiver:

[23] : BB measurement → "U_x (BB)" [18]

[2], [10] : Distortion parameters as required

[17] : Adjust phase U_x of $\Delta\tau/\Delta\varphi$ or $\Delta U/U_o$ for coincidence of forward and backward sweep; 180° phase uncertainty can be removed with blanking gap ([11] on RMS-5); switch off pushbutton function [17].

Evaluation of the results is carried out on the screen of the RME-5 (simultaneous display of $\Delta U/U_o$ and $\Delta\tau$ or $\Delta\varphi$!), with the internal evaluation facilities described in Section 3.7, or on an external computer connected via the IEC bus.

The auxiliary connection between output [10] (RMS-5) and input [25] (RME-5) permits insertion of frequency markers in the BB distortion results. This is absolutly necessary if the demodulator being tested suppresses the sweep signal. Depress pushbutton "U_x (IF)"; LED on. Phase correction - pushbutton [17] depressed - with the arrow pushbuttons under [18] is also necessary.

3.8.5.3 Return loss at the demodulator input

See Section 3.8.7.2

3.8.5.4 Measuring the demodulator idle noise

For this measurement, a noise-free sinusoidal signal with minimum harmonic content ("quiet tone") with the IF center frequency 70 MHz (or 35 MHz) is required. This is provided by the RMS-5 Generator at output [12], if the Generator is equipped with the optional feature"IF calibration generator".

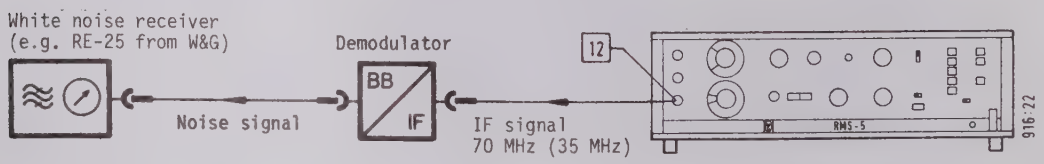


Figure 3-29 Measuring the demodulator idle noise

Select the required intermediate frequency with switch [4] on the RMS-5. No further settings are required, as the signal is transmitted with a fixed level of +5 dBm.

The intrinsic noise power generated in the demodulator is measured at the baseband frequency with a white noise receiver or selective level meter. If the White Noise Receiver RE-25 from W&G is used, the prespecified relative level can be set direct and the noise can be read-off direct in pW0p.

3.8.6 MEASUREMENTS ON MODEM LOOPS (BB-BB)

Measurements on modem loops, i.e. on tandem connected modulators and demodulators, are also carried out frequently. As these are measurements between BB terminals, only the distortion measurements need to be mentioned with respect to use of the RM-5.

3.8.6.1 Distortion measurements $\Delta\tau$, $\Delta\varphi$ and $\Delta U/U_0$

Settings on the RMS-5 Generator:

[8], [9] : Test frequencies as required

[19] : Sweep frequency as required

[17] : Sweep voltage $\hat{U}_A = \hat{\Delta F}/S_{Mod}$; $\hat{\Delta F}$ as required (according to system), it is assumed that S_{Mod} is known

[16] : Increase test voltage U_M until sweep curve is free of noise

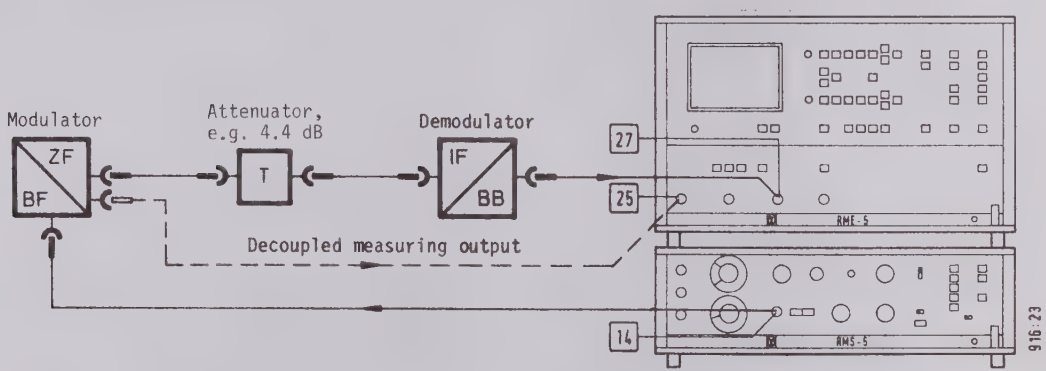


Figure 3-30 Distortion measurements on the modem loop

Settings on the RME-5 Receiver:

[23] : BB measurement ⟶ "U_x (BB)" [18]

[2], [10] : Select required distortion parameters

[17] : Correct phase of U_x (see Sections 3.6.7 and 3.6.8); after this switch off pushbutton function [17].

[18] : "U_x (IF)" if IF is connected, see Figure 3-30: dotted connection, correct the phase of U_x.

For level matching, an attenuator of (generally) 4.4 dB should be connected between the modulator output and the demodulator input.

The dotted auxiliary connection to input [25] (RME-5) in Figure 3-30 permits calibration of the x axis - with pushbutton "U_x (IF)" [18] depressed - with the sweep limits $F_o \pm \Delta F$ and the frequency markers M, which is very useful for evaluation of the distortion curves.

This permits the sweep width $\hat{\Delta F}$, which is set up with potentiometer [17] of the RMS-5, to be displayed direct on the screen of the RME-5. The sweep width should be set up with the "automatic sweep width reduction" switched off and at a low measuring frequency (pushbuttons [8]).

The test deviation Δf set up on potentiometer [16] "U_M" can be checked with the IF connected on the RME-5, using the r.m.s. value deviation meter - Δf displayed on the screen - (e.g. test deviation Δf corresponding to r.m.s. channel frequency deviation of the system being tested).

Evaluation of the results is carried out with the internal facilities described in Section 3.7 or on an external computer connected via the IEC bus.

3.8.7 MEASUREMENTS ON IF MODULES (IF-IF)

3.8.7.1 Distortion measurements $\Delta\tau$, $\Delta\varphi$ and $\Delta U/U_o$

The measurements are basically the same as those described in Section 3.8.2.1. The setting values for the IF level, test deviation, and sweep width must be selected according to the user's requirements.

Note: By depressing the ΔP_I pushbutton (LED on) in pushbutton row [2] or [10] of the RME-5, the IF frequency response can be displayed simultaneously with the distortion result (see also Section 3.8.2.2).

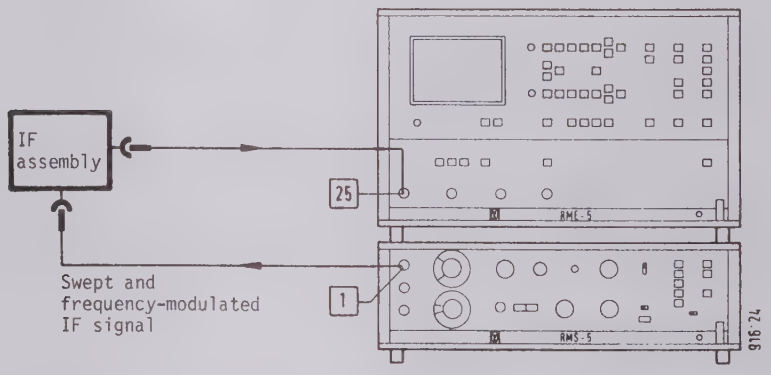


Figure 3-31 Distortion measurements on an IF module

3.8.7.2 IF return loss a_r and group delay $\Delta\tau$

For measurement of return losses in the IF band, the IF Return Loss Measuring Bridge RFZ-4 or RFZ-14 which is available as an accessory must be used.

The measuring range (full screen height) which can be selected on the RME-5 extends from 8 to 80 dB; measuring mode ΔP_{II}.

The use of an adapter from our universal connector system Versacon® 9 on the test unit connection of the Measuring Bridge ensures that the Bridge can be connected directly, without further adapters or cables, to the unit being tested. This avoids degradation of the results.

For the a_r measurement, the configuration shown in Figure 3-32 must be set up.
This measuring configuration makes it possible, in addition to the a_r result (ΔP_{II} pushbutton depressed), to display a distortion resultor an IF frequency response ΔP_I at the same time, as shown in Figure 3-33b.

Practically, the group delay $\Delta\tau$ will often be displayed together with the return loss in order to permit mutual adjustment or to observe mutual interactions. The settings of the RMS-5 and the RME-5 are based on the assumption that the group delay will be measured simultaneously with the return loss a_r. A further prerequisite is that a measuring frequency < 1 MHz is selected for the group delay, as the "automatic sweep width reduction" reduces the sweep width at higher measuring frequencies, and would therefore reduce the IF bandwidth over which the return loss a_r is measured.

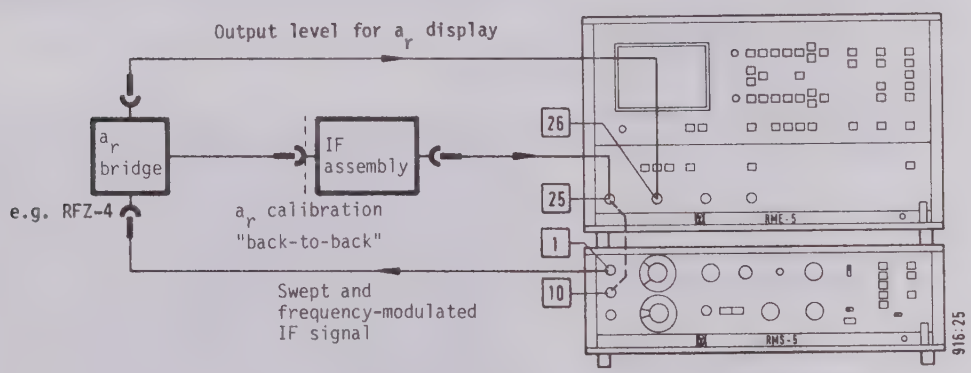


Figure 3-32 Return loss of an IF module

Settings on the RMS-5 Generator:

[2], [13] : Set the required level; in order to compensate for the bridge loss, this must be 6 dB higher than required by the unit being tested.
[4] : Center frequency 70 MHz (or 35 MHz)
[5], ([7]) : Sweep width $\Delta\hat{F}$ as required (depending on system)
[8] : Test frequency as required, f_M < 1 MHz!
[19] : Sweep frequency as required
[16] : Select the test deviation (r.m.s. channel frequency deviation) according to the system value or increase it until the $\Delta\tau$ result is no longer noisy, without losing the fine structure of the a_r result. (Noisy $\Delta\tau$ results can be improved by "noise averaging" on the RME-5, see Section 3.7.1).

Settings on the RME-5 Receiver:

[22] : IF measurement ⟶ "U_x (IF)" (with phase correction as in Section 3.6.7 if necessary)
[21] : IF to match IF of unit being tested
[2] : "$\Delta\tau$" measurement ⟶ if result noisy: select [5] "averaging" (see Section 3.7.1)
[10] : "ΔP_{II}": a_r result display ⟶ check the fine structure by reducing the r.m.s. value deviation Δf ([16] on the RMS-5) if major changes are made to the frequency response.

Calibration of the a_r measurement with the test object disconnected:

Calibration of the Measuring Setup RM-5 is carried out with a short circuit (r = -1) at the measuring output of the Bridge in the required sweep range.

Establish the short circuit with the aid of the short circuit adapter (Order No. S 818) supplied with the bridge.

For calibration, modify the measuring configuration by establishing a connection between the output [10] of the RMS-5 and the P_I input [25] of the RME-5 (dotted line in Figure 3-32) instead of the connection from the output of the test object to the P_I input [25] of the RME-5. This connection is necessary for tracking control of the P_{II} input [26] of the RME-5.

In the case of total reflection (r = -1), the return loss is 0 dB, and this is used as the reference line for the a_r measurement; see Figure 3-33a, line ►. In order to reduce the intrinsic error of the measuring setup as far as possible, reduce the output level in 10 dB steps until the reference line on the screen is positioned at 10 dB value of the ΔP_{II} calibration closest to the expected measured value; see Figure 3-33a, line ►► .

Example: Expected measured value a_r = 32 dB
Reference line at a_r = 30 dB (Figure 3-33a, line ►►►)
Output level to be reduced by 30 dB

The position of the reference line must be corrected with potentiometer [9] if it deviates from the required position (line ►►).

a_r measurement with test object connected

Now reconnect the test object to the Measuring Bridge and increase the IF output level on the RMS-5 with switch [13] to its original value (in the example: by 30 dB).

Note: This calibration is valid for the a_r measurement only if the test deviation Δf and the test frequency f_M, which were set up for the $\Delta\tau$ measurement before start of calibration, are not changed. The reason for this is that the energy distribution between the IF carrier and the sidelines varies if the test deviation and test frequency are changed. This is important, as the level at the P_{II} input [26] is measured selectively.

If it is not desired to display a further result simultaneously on the screen with the a_r result, the measuring configuration in Figure 3-32 can be modified by removing the connection between the output of the test object and the P_I [25] of the RME-5 and replacing it by the connection shown as a dotted line. The output of the test object should be terminated with a 75 Ω resistor (BN 922). Switch off the test deviation and "automatic sweep width reduction" on the RMS-5. On the RME-5, ΔP_{II} can then be selected with pushbuttons [10] or [2].

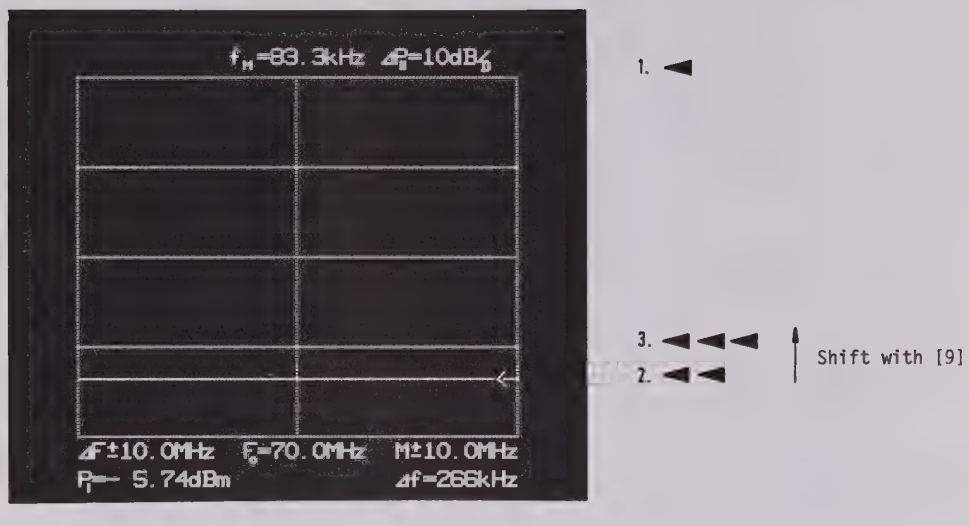


Figure 3-33a Shifting the reference line (r = -1) to the 30 dB graticule line during calibration of the a_r result

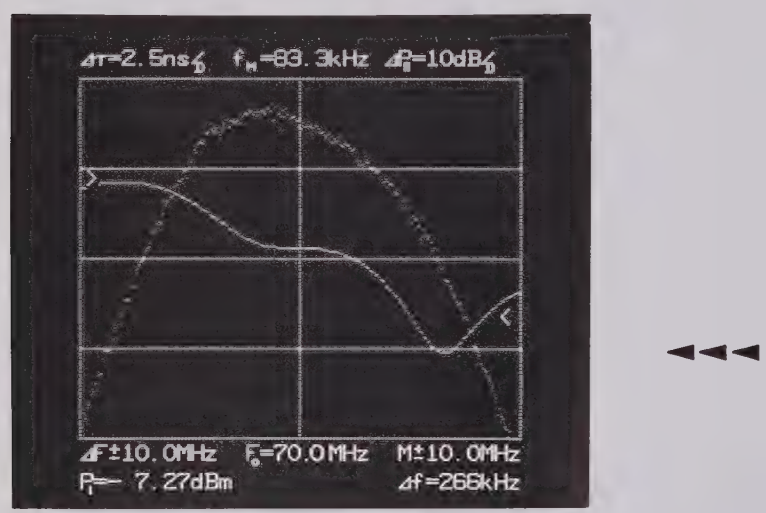


Figure 3-33b IF return loss a_r and group delay $\Delta\tau$ after calibration of the a_r result

3.8.7.3 IF frequency response ΔP_{II}

The IF frequency response ΔP_{II} is determined by selective measurement of attenuation curves with a test bandwidth of approximately 1.5 MHz. The level-linear display range is 40 dB, but the maximum measuring range (ΔP_{II} = 20 dB/DIV) on the screen of the RME-5 is 80 dB.

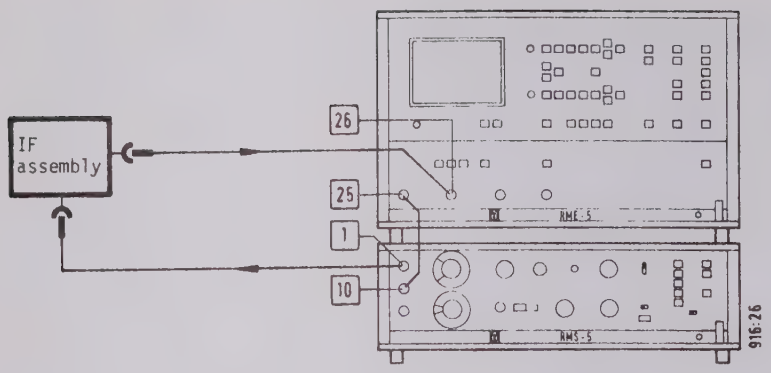


Figure 3-34 Selective measurement of the attenuation curve of an IF assembly

Settings on the RMS-5 Generator:

[2], [13] : As required, but level at input [26] of the RME-5 $\leq$ -10 dBm
[4] : Center frequency 70 MHz (35 MHz) to match IF of test object
[16] : $\Delta f = 0$
[6], [7] : $\hat{\Delta F}$ as required
[19] : Sweep frequency as required

Settings on the RME-5 Receiver:

[22] : IF measurement ⟶ "U_x (IF)" (see Section 3.6.7 for phase correction)
[21] : IF to match IF of test object
[2], [10] : "ΔP_{II}"

The connection between [10] (RMS-5) and [25] (RME-5) is required for tracking control of the input [26] and for generation of the deflection signal U_x.

Calibration of the screen display, i.e. positioning of the 0 dB line, is carried out with a back-to-back connection between [1] (RMS-5) and [26] (RME-5); note the maximum level of -10 dBm at input [26]

3.8.8 MEASUREMENTS ON SATELLITE TRANSMISSION SYSTEMS

The measuring technology used on FM radio-link systems can be used without restrictions on satellite systems with frequency modulation.

In contrast to the sweep frequency of 70 Hz commonly used in radio-linkmeasuring tasks, a sinusoidal sweep frequency of 18 Hz is prescribed for end to end measurements via satellites. The reason for this low sweep frequency is that measurements must be carried out with the smallest possible bandwidth, due to the expected high noise components in the test signal after transmission; on the other hand, a correct result can be obtained only if the maximum possible bandwidth - sweep frequency-ratio is used.

The number of measuring frequencies is restricted to 92.593 kHz (for systems with up to 60 channels), 277.778 kHz (for systems with more than 60 channels), and one of the color sub-carrier frequencies 3.58 or 4.43 MHz for TV transmission.

With the measurements prescribed for the communication satellite system INTELSAT, the following can be executed with the RM-5 measuring setup:

- IF-IF amplitude frequency response ΔP_I,
- IF-IF group delay distortion $\Delta\tau$ (INTELSAT IV only),
- BB-IF group delay distortion $\Delta\tau$ (INTELSAT III only),
- BB-BB linearity distortion $\Delta U/U_o$.

The measuring configurations and execution of the measurements are described in Sections 3.8.1 and 3.8.2 of these operating instructions. In addition, it is recommended that the group delay distortion of the modulation equipment in the ground station be checked before carrying out measurements via the satellite-link.

A further important measuring task is checking the IF filters used with respect to amplitude frequency response ΔP_I and group delay distortion $\Delta\tau$. The IF filters in the ground stations on the transmitting and receiving sides are used for selection of the various IF transmission bandwidths, which means that the requirements for these filters are particularly high. The bandwidths of the filters vary between 1.25 and 36 MHz, depending on the number of voice grade channels being transmitted.

For checking IF filters with narrow bandwidths, the facility for inserting continuously variable frequency marks in the screen display for precise adjustment of the sweep width is interesting; see Section 3.5.1.4.

Measurements at the RF level with the aid of the RM-5 Measuring Setup and "sweepers" or "down converters" are also possible. Further details of these measurements can be found in Section 3.8.1.

3.8.8.1 Measurement at the RF level

For measurements at the RF level, further test equipment is required in addition to the RM-5 Radio-link Measuring Setup, depending on the measuring task. As these are commercially available equipment (e.g. made by Scientific Atlanta), only a basic description of two of the possible measuring tasks is included here.

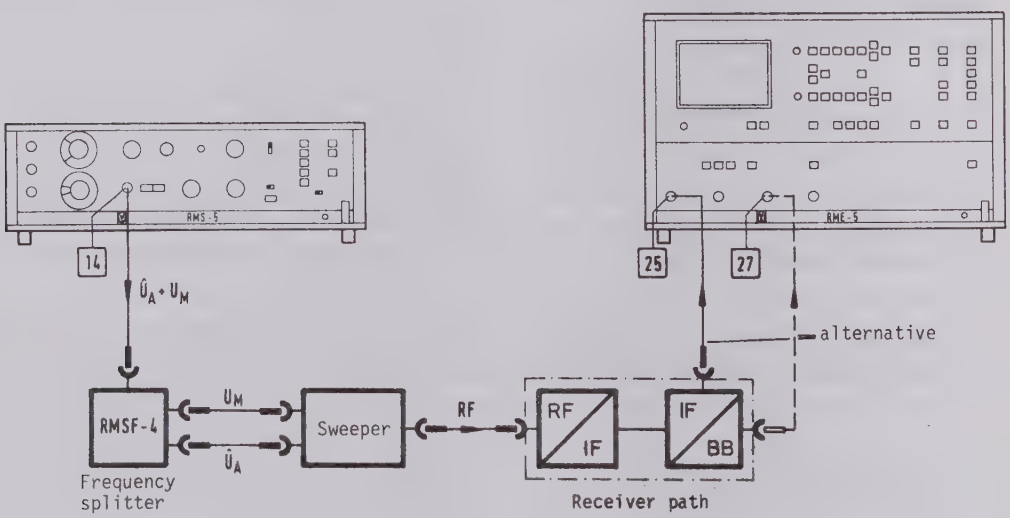


Figure 3-35 Measurements at the RF level with RM-5 and sweeper

For measurements on the receiver path of a radio-link or satellite reception system, a swept and frequency-modulated RF signal with low distortion values is required. A "sweeper", which is driven by the separate signals U_M and $\hat{U}_A$, directly generates the required RF signal. The sum signal $\hat{U}_A + U_M$ available at output [14] of the RMS-5 is split into a measuring signal U_M and a sweep signal $\hat{U}_A$: carried out by the Frequency Splitter RMSF-4, which is available as an accessory for the RM-5.[1] Measurement is done at either the IF or BB output of the receiver path.

The measuring configuration for the above measurement is shown in Figure 3-35.

It is naturally also possible to measure the transmit path. The transmitted signal is provided by the RMS-5. The RF signal at the outputof the transmitter path is converted down to the IF level with the aid of a "down converter", and is connected to the P_I input of the RME-5 for measurement; see Figure 3-36.

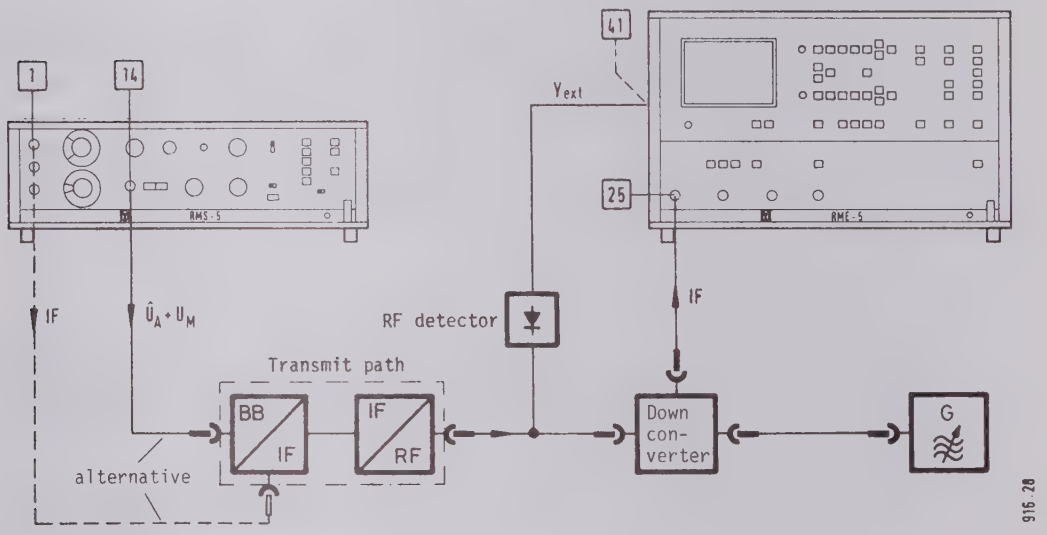


Figure 3-36 Measurements at the RF level with RM-5 and down converter

With the aid of an RF detector, it is also possible to display the RF frequency response on the screen of the RME-5. For this purpose, the output signal of the detector is connected to the rear input [41] "Yext" and pushbutton "Y_{EXT}"is depressed in row [2] or [10] (LED on). The measuring range for full screen height can be selected between 8 and 800 mV.

The sweep curve can be recorded with the recording facilities described in Section 3.9.

With the aid of the RM-5, sweeper, and down converter, it is also possible to carry out RF-RF end to end measurements (e.g. transponder measurements on satellite systems) or to measure the characteristics of RF assemblies on the bench.

---

1) Order No. BN 696/00.08

3.9 RECORDING RESULTS OF MEASUREMENT

3.9.1 VIDEO PRINTOUTS/LARGE DISPLAY

The monitor of the RME-5, which operates on the video principle, permits a large display or printing of the current screen information with the aid of a video printer connected to video output [42]. The output, which contains all important parameters, is a rational and error-free method of recording the results.

The video printer or the external monitor is connected via a coaxial cable with BNC connectors to the output socket [42] on the rear of the RME-5. Considerable lengths of cable can be connected between the RME-5 and printer (or external monitor), which means that the results can be recorded at some other location. The current video signal is continuously present at the output; initiation of video recording is carried out on the printer.

During the duration of the recording, it is necessary to maintain a static display. Do not change any settings on the RM-5 while this is being done. It is also recommended to freeze the display during the printing operation with the pushbutton "START/STOP" [12] (or [10]) on the RME-5.

Video output

For connection of a video printer or external monitor (large display)

Socket	:	BNC
Output impedance	:	75 Ω
Output signal	:	Video positive/625 lines
Output voltage at $Z_{out} = Z_L$	:	V_{pp} (Composite video signal) = 1 V

3.9.2 XY PLOTTER OPERATION

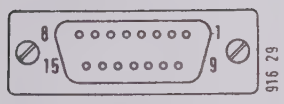
In addition to recording of the complete screen display, it is also possible to log the distortion curves by means of an XY plotter. All commercially available XY plotters can be connected to the XY plotter interface, which is available as an option (BN 917/00.01).

Before installing the XY plotter interface on the rear of the RME-5 (see Figure 3-4b), the sensitivity of the outputs must be matched to the plotter to be used. Two values can be selected with switch S 1 - see Figure 5-3 for location.

S 1/1 and S 1/2 open: 0.4 V/cm
S 1/1 and S1/2 closed: 0.1 V/cm

In addition, it is possible to reverse the polarity of the "pen-lift" function with the pen-lift strap. When the interface leaves the factory, strap b-c is fitted; see Figure 5-3.

The enclosed cable K 379 is connected to the socket of the XY plotter interface. The open end of the cable is connected to the external control socket of the plotter with the aid of the information in Table 3-3.



Viewed on pin side

Plug connector of XY plotter interface for K 379

Plug pins	Function	Wire color in cable	Connection point in plotter[1)]
1	Ground	Screen	
2	Output "+X"	Grey	.....
3	Output "-X"	White	.....
4	Output "+Y"	Green	.....
5	Output "-Y"	Yellow	.....
6	Pen-lift	Brown	.....
7	Pen-lift	Red	.....
8	Ground	Screen	
9	Ground	Screen	
10 ... 15	not used		

Table 3-3b Pin assignments in plug (K-379)

Recording of sweep measurements with measurement results can be carried out on special preprinted forms. All important parameters (information on screen, selected functions) can be recorded in tables above the two spaces for the curves; plotter form BN 0917/00.79.

The sensitivity of the plotter must be adjusted in the X and Y directions. Set the pen of the plotter to the zero point printedon the form; see Figure 3-37.

Recording of sweep measurement results [2] or [10] is carried out by depressing the pushbutton "START/STOP" in the appropriate row of pushbuttons. If the screen currently displays two results, depression of the pushbutton "START/STOP" [2] (LED on) causes the curve (including auxiliary lines) see Figure 3-38)) to be recorded on the left of the form. After a recording duration of 20 seconds (measured curve) the pen returns to the zero point.

If the pushbutton "START/STOP" [10] is now depressed (LED on), the second curve is recorded on the right of the form.

Recording of the measured curves [2] and [10] can, of course, be carried out in the reverse order.

During operation of the plotter, recording can be interrupted by depressing the corresponding "START/STOP" pushbutton (LED off), and the pen returns to the zero position.

---

1) To be entered by user

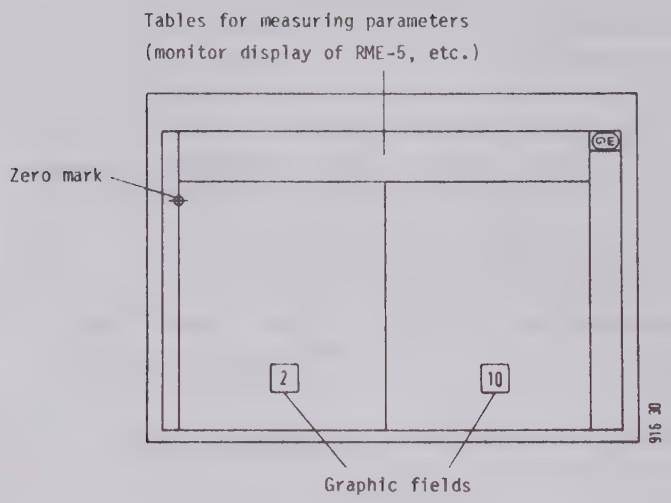


Figure 3-37 Plotter form (DIN A4) with 2 fields, BN 0917/00.79

The plotting speed can be increased by a factor of 4 by depressing the direction pushbutton "⇧" [5]; select the speed according to the amount of ripple on the display results. The plotting speed can be reduced again by depressing the "⇩" pushbutton [5].

Figure 3-38 shows, with the aid of a measured curve, the facilities offered by the RME-5 with the plotter interface for inclusion of auxiliary lines in the results.

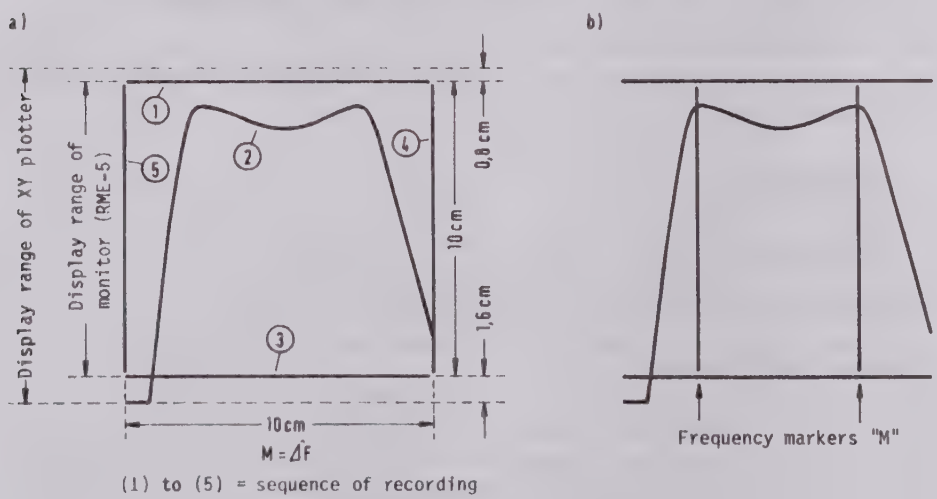


Figure 3-38 a) XY plotter record; dimensions, format
b) Curve as in a), but with frequency markers inserted

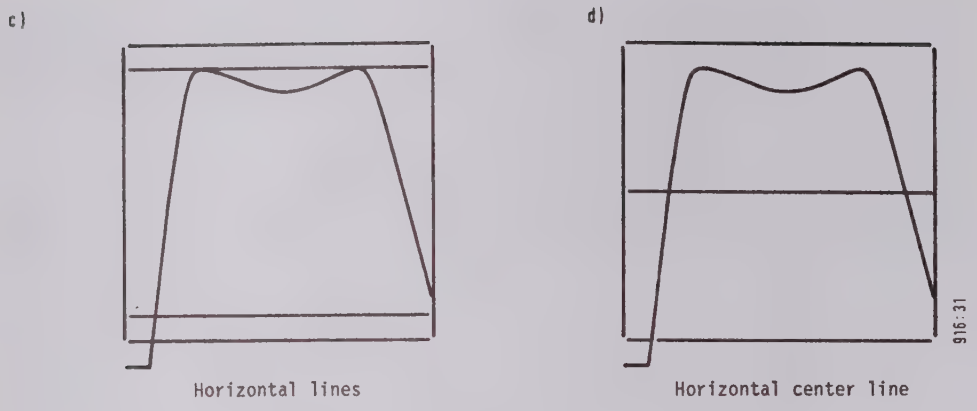


Figure 3-38 c) Curve as in a), but with horizontal lines inserted (M = ΔF)
d) Curve as in c), but with " ⌃ = 0"

3.10 TEST FREQUENCY REMOTE CONTROL OF THE RMS-5

For specific applications, it is useful to replace manual test frequency switching by remote control with the aid of a suitable control unit. The control unit is connected to the remote control socket [30] on the rear of the RMS-5 Generator. The pin assignments are shown in Table 3-4.

Disable the test frequency selection pushbuttons [8] and [9] by connecting pin 9 to ground; this can also be done by connecting an L-signal to the appropriate pin of socket [30].

It is possible to supply a control unit with power via pin 10 of the remote control socket [30]. Even if the test frequencies are remotely controlled, the selected "automatic sweep width reduction" remains active.

Remote control socket [30] (viewed on contact side)

Terminal point	Function
1	Select test frequency 27.8 kHz or 25 kHz
2	Select test frequency 55.6 kHz or 50 kHz
3	Select test frequency 92.6 kHz or 83.3 kHz
4	Select test frequency 277.8 kHz or 250 kHz
5	Select test frequency 555.6 kHz or 500 kHz
6	Select test frequency 2.4 MHz or color sub-carrier (Option)
7	Select test frequency 5.6 MHz or color sub-carrier (Option)
9	Disable test frequency pushbuttons [8] and [9]
10	+5 V/max. 100 mA
11	+12 V/max. 65 mA
12	-12 V/max. 80 mA
14	Chassis-ground

Table 3-4 Pin assignments on the test frequency remote control socket [30]

3.11 REMOTE CONTROL OF RME-5, <IEC 625> INTERFACE BUS

3.11.1 MISCELLANEOUS

For applications that are intended to include external control of the RME-5 (by desktop computer, process computer) the internal functions can be remote controlled and the measured results requested for. Remote control card BN 853/07 is available for this purpose and may be mounted in the RME-5. The <IEC 625> Interface Card corresponds to specification DIN IEC 66.22 and IEC Standard 625. The <IEC 625> Standard has the electrical characteristics of IEEE-488-1975 or the HP-IB Standard. The only difference is in the type of plug/receptacle used. Wandel & Goltermann has published a Brochure "Interface Bus <IEC 624>, which contains a great deal of information about the implementation of the Interface Bus <IEC 625>. This is available from W & G.

3.11.1.1 Instrument configurations

An RME-5 that is not equipped with the <IEC 625> Interface Card can be retrofitted with it at a later date.

The interface card can be plugged into the back panel of the RME-5 after the dummy panel has been removed. Figure 3-4b shows the plug-in space P intended for this interface card.

If the card is delivered as a separate item, it should be checked whether or not the following soldered straps have already been assembled and whether the address and the parallel poll switches are in their required settings.

Short circuiting straps as follows:

A0
B0
C4
JL
RST 7,5
CLR

If the instruction "Interface Clear" (IFC) shall evoke a response from not only the interface but also the instrument, then the CLR short circuiting strap should be in place. In this case the IFC instruction simultaneously causes "Device Clear" and "GO TO LOCAL". The result is the same as when the instrument is switched on and its battery is in discharged condition.

3.11.1.2 Address switch, S 1

The S 1 switch settings, A 1 to A 5 (see Fig. 5-4) are to be set at the chosen instrument addresses.[1)] Address Ø5 has been chosen as an example in this section. However, as no other instrument is permitted to have the same address as an instrument already connected to the bus, a check should be made to determine if there is such a conflict. The S 1 switch settings LON and TON are used for setting talker and listener addresses. Since the RME-5 allows the mode Talker/Listener only, both switch settings are to be at OFF.

---

1) The interface is delivered with the bus adress 13 (Standard address)

Remark: A bit set to 1 "ON" when the switch is pressed in the direction of the figures. "OFF" corresponds to "Ø".

3.11.1.3 Parallel poll switch, S 2

The number of the I/O line on which the RME-5 reacts to a parallel poll interrogation is defined as the parallel poll address. One of the switch elements PPR 1 to PPR 8 (corresponding to DIO 1 to DIO 8) - see parallel poll switch in Fig. 5-4 - is set as wanted (i.e. the switch should be pressed to any side on which PPR is lettered. Only one switch element should be actuated.

3.11.1.4 Bus interconnections

The special Interface Cable K 343 (1.2 m long) or K 344 (2 m long) is to be used for interconnecting the RME-5 with the control unit or other units of the <IEC 625> bus system. An adaptor S 834 is available for interconnecting the RME-5 to an IEEE-488 or HP-IB type of bus.

3.11.1.5 Implementing <IEC 625> Interface Functions

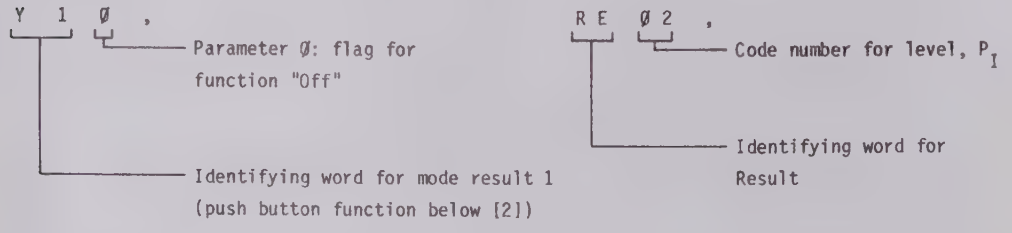
According to the <IEC 625> Standard the following instructions of the interface functions are effected for the RME-5 by the <IEC 625> Interface

SH 1	Source handshake - whole configuration
AH 1	Acceptor handshake - whole configuration
T 6	Talker - all functions, except for "talk only" and secondary addressing
L 4	Listener - all functions, except for "listen only" and secondary adressing
SR 1	Service Request - whole configuration
PP 2	Parallel-Poll - established by a switch
DC 1	Device Clear - whole configuration
DT 1	Device Trigger - whole configuration

3.11.2 PROGRAMMING

3.11.2.1 General Information for Programming

The setting of the RME-5 (e.g. mode, measurement range etc.) is done with a data set (programming data) that is transferred to the REM-5 from the control unit. Usually, the program data set comprises one or more identifying letters followed by a code number or by a parameter field. For example:


Y 1 Ø ,
Parameter Ø: flag for function "Off"
Identifying word for mode result 1 (push button function below [2])
R E Ø 2 ,
Code number for level, P_I
Identifying word for Result

The data set is terminated or separated by a comma.

To begin a measurement, i.e. to request a static result or a measuring curve, the RME-5 is triggered by "device trigger" (DT 1). If the measurement is terminated, the RME-5 signals "Service Request", if programmed accordingly, or the control unit scans the status byte until it has recognized that the measurement is ended. After the control unit requests measured results from the RME-5, the results are transferred to the control unit. The type of transferred result depends upon the just executed measurement mode.

The resulting data comprises numerical characters that also incluce algebraic signs and decimal points, when necessary. A comma terminates a numerical data set. If the RME-5 has been programmed accordingly, it transmits to the control unit a "Service Request" after the end of a measurement.

Likewise, status information about the current status of the RME-5 is transferred to the computer when the checking byte is required; see para. 3.11.2.7.

3.11.2.2 Setting the RME-5

The programming data are defined remote control information addressed to the RME-5, so that it sets up its various functions to carry out a measurement. The RME-5 is prepared to receive data as soon as it has been addressed as a listener. Then it goes into remote control mode, indicated externally by the red LED (ON) above key [24], REMOTE.

The programming data comprises a number of strings; Fig. 3-38. Each string comprises two or more characters. A string is output as serial from left to right. Each string brings about the setting of a certain function of the instrument, and in most cases it corresponds to an individual function on the front panel. The last character of a string is always a comma.

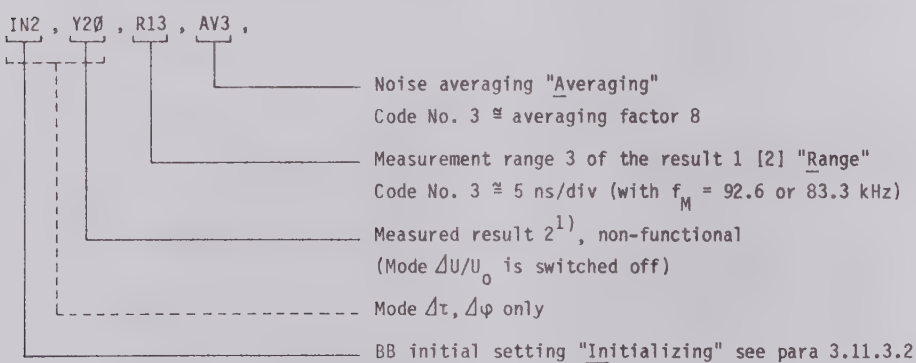

IN2 , Y2Ø , R13 , AV3 ,
Noise averaging "Averaging"
Code No. 3 ≙ averaging factor 8
Measurement range 3 of the result 1 [2] "Range"
Code No. 3 ≙ 5 ns/div (with f_M = 92.6 or 83.3 kHz)
Measured result 2 1), non-functional
(Mode $\Delta U/U_0$ is switched off)
Mode $\Delta\tau$, $\Delta\varphi$ only
BB initial setting "Initializing" see para 3.11.3.2

Fig. 3-38 Programming data string, (setting data according to para. 3.11.4.1)

The characters allowed in any string position are listed in the programming words (see Section 3.11.4) and in the corresponding data specifications of the RME-5 as detailed in Section 1 of this Operating Manual.

The modes and the parameter range of the remote controlled RME-5 are the same as with the internal microprocessor control (i.e. manual operation).

In most cases when the last comma of a parameter string has been transferred, the input data is read-in to the corresponding memory. As with manual operation, the microprocessor evaluates the entries in order to assure that they are within the permissible range and limits them before they are read-in to the memory.

1) Measured result 2 corresponds to the mode below key function [10] of the RME-5

The programming words for the settings of the RME-5 are listed in para. 3.11.4 (or 3.11.3).

3.11.2.3 Examples for setting-up the RME-5

In the following, some examples are given for the remote control of the RME-5. They are related to the HP 85 desktop computer.

Interface select code of computer: 7
Bus address of RME-5 (Talker/Listener): Ø5

} 7Ø5 "Interface Bus Address"[1)]

Example A

Setting of the RME-5 according to the example shown in Fig. 3-38; "$\Delta\tau$ setting"

The following statements are to be keyed in; (press "END LINE" after every statement):

```
RESET 7 ──────────────────────── Reset RME-5 to initial setting "IN1",
                                 see 3.11.3
OUTPUT 705 ; "IN2,Y20,R13,AV3," ─ Send output string (RME-5 operates in
                                 "REMOTE" mode)
```

Example B

Setting according to Example a), with other output string

```
RESET 7
OUTPUT 705;"IBF,DP,R13,Y20,AV3,"
                    │  │  │  │  └── "Noise averaging"
                    │  │  │  └───── "Result 2 omitted"
                    │  │  └──────── "Measurement range R13"
                    │  └─────────── "Measurement range Δτ, Δφ"
                    └────────────── "BB signal input"
```

Example C

Insertion of horizontal lines

Horizontal lines with separation ≙ of 15 ns shall be inserted in the initial setup "1N1", $\Delta\tau$, $\Delta\varphi$ result, measuring range 10 ns/D at f_M = 92.6/83.3 kHz; subsequently the horizontal lines are switched off again.

The following statements are to be keyed in:

```
RESET 7 ──────────────────────── - Instrument is set to initial setup "IN1"
OUTPUT 705 ; "HL15.," ──┐
                        └─────── - Send output string, value of ≙ furnished with decimal
                                   point
OUTPUT 705 ; "HLOFF," ──┐
                        └─────── - Switch off horizontal lines
```

1) The Interface is delivered with the bus address 13 (standard address)

Example D

Text entry in CRT screen of RME-5

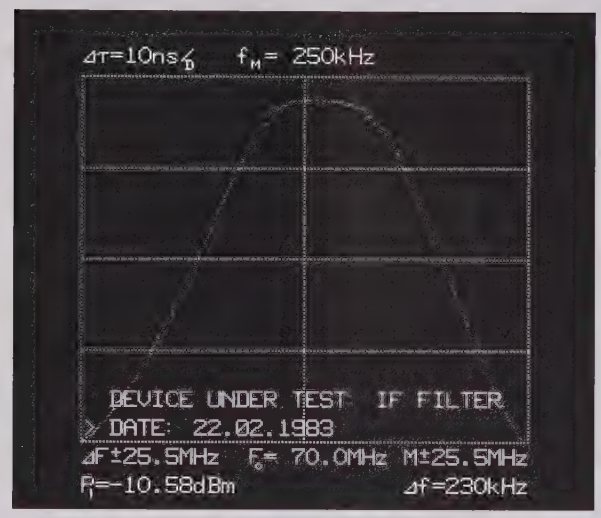


Fig. 3-39 Distortion curve $\Delta\tau$ with comments in lines 12 and 13

In order to insert the text shown in Fig. 3-39 the following statements are to be made:

```
OUTPUT 705;"Y20,DP,R15,L12 DEVIC
E UNDER TEST: IF FILTER,L13 DATE
: 22.02.1983,"
```

"Setting-up measuring mode and range"

"Text entry in L 12 and L 13"

3.11.2.4 Transfer of measured results (CRT screen information of RME-5)

After the setting-up of the RME-5, the CRT screen information may be requested for; i.e. static results and distortion curves. The RME-5 is prepared to supply data as soon as it has been addressed as a "Talker".

Depending upon the programmed output mode - programming words of form RE $X_3X_2X_1X_0$ (see para. 3.11.5) - the RME-5 transfers a measured data string or status string (as answers to checking word, see 3.11.2.7).

Just a numerical printout is involved here.

In the case of the measuring data (CRT screen information), the type of result that is to be transferred is determined by the last previous programmed measurement mode.

The units, dB, ns, %rad, and so on are not transferred from the RME-5. But they are observed to be in the type of result (RE$X_3X_2X_1X_0$) and can also be written into the program.

The output format associated with the type of result is explained in Section 3.11.6. According to the result and ultimate measuring range, the decimal point and, if necessary, the algebraic sign are to be defined in the appropriate format statement.

3.11.2.5 Transfer of static results, programming example

Compare para. 3.11.5.1 "Programming words".

The programming example refers to Desktop Computer HP-85; IEC Bus address: 7Ø5

The following statements are to be programmed:

```
10 CLEAR @ DISP "Welches statisc
he Ergebnis soll eingelesen werd
en?                RE0Ø, ... RE09,"

20 OUTPUT 705 ;"@01011,T1,"
30 INPUT E$
40 OUTPUT 705 USING "K" ; E$
50 TRIGGER 705
60 ON INTR 7 GOTO 80
70 ENABLE INTR 7;8
80 STATUS 7,1 ; S
90 IF S#8 THEN GOTO 90
100 ENTER 705 USING "%,%K" , A
110 DISP USING 120 ; A
120 IMAGE SDD DD
130 END
```

Establish interface mode and trigger mode
see 3.11.4.3 and 3.11.4.4

Input of RE .. in E$

E$ sent to RME-5

Execute single measurement with program end identification, SRQ

Transfer result

Output formatting for REØ2

Entry: "RE02," e.g. Level P_I (see Programming words according to 3.11.5.1)

Output: -10.61

The output formatting (line 120) is suitable for the resulting data "REØ2 to REØ7".

Line 120 should be modified for the output of f_M (REØØ), Δf (REØ1), horizontal lines (REØ8) and the LIN/PARAB component (REØ9) and so on; see Section 3.11.6, "Result Output Formats".

3.11.2.6 Transfer of the dynamic results

See para 3.11.5.2 "Programming words"

With the interrogation of the points on the curve by means of the computer, not only the "y" values within the CRT screen raster (RME-5) are taken into account (205 values), but also the 51 amplitude level steps outside of the raster image are interrogated. The internal calibration of the CRT screen raster with the "y" values is shown in Fig. 3-40.

If the y values of 2 points on the curve are known "□" (see Fig. 3-40), then the absolute distortion value may be calculated according to the following relationship. The two points on the curve can for instance represent the extreme values of "y". Interrogation with programming word "REØA" or "REØB" is possible.

$$\text{Absolute distortion value} = \frac{y_1 - y_2}{\Delta y} \times \text{measuring range (div)};\ \Delta y = 51$$

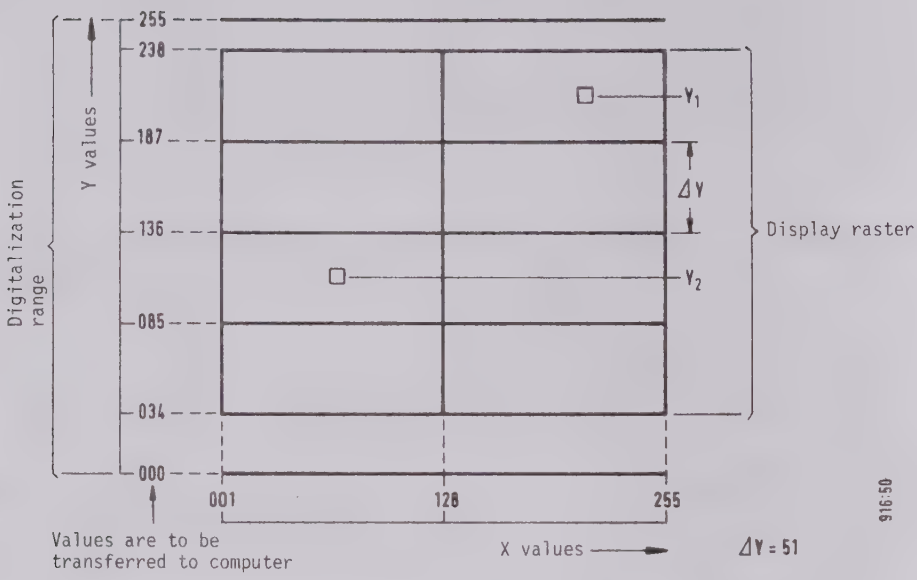


Fig. 3-40 Calibration of the CRT screen raster with "y" values
definition range of curve points P (x/y):
{ØØ1 < x ≤ 255; ØØØ < y ≤ 255}

Example A "Entry of a single value"

The "y" value shall be requested at the center frequency, F_o, on the distortion curve shown in Fig. 3-39 ($\Delta\tau$ result). "F_o" corresponds to the X value of 128; see Fig. 3-40. According to 3.11.5.2, the programming word is: "RE1128", and the following statements are related to the HP-85.

```
OUTPUT 705 USING "K";"RE1128,"  ——— Data output for measured result
ENTER 705 USING "%,%K,3Ø"; Y    ——— Transfer of result with formatting
DISP Y

224 ——— Y value
```

Example B "Transfer of the complete curve, plotting"

The following program loads into the computer (YØ-String) the 255 "y" values of the measured result shown in Fig. 3-39. This involves the distortion result 1; with that, the current programming word is: "RE1000,". The following statements are related to the HP-85 Computer.

```
10 DIM Y$[255]
20 OUTPUT 705 ;"@01011,"
30 OUTPUT 705 USING "K" ; "T1,R
   E1000,"
40 TRIGGER 705
50 ON INTR 7 GOTO 70
60 ENABLE INTR 7;8
70 STATUS 7,1 ; S
80 IF S=8 THEN 60
90 ENTER 705 USING "%,%K" ; Y$
100 OUTPUT 705 USING "K" ; "T0,"
110 DISP "Kurve ist in Y$ abgesp
    eichert !"
120 PAUSE
```

- Prepare Y$ storage for transfer
- Set interface mode (see 4.11.4.3)
- Transmit instruction for trigger mode (single), measuring curve 1 "RE1000,"
- Transmit trigger instruction
- Initialize interrupt
- Enter SRQ status bit
- Evaluate status bit
- Load y result in computer
- Set trigger mode (free running)

The "y" values of the distortion curve can be represented in graphics by means of the following program (statements 200 to 300); "CONT" key is depressed until statement 120 of the above program has been processed.

```
200 GCLEAR
210 SCALE 0,255,34,238
220 XAXIS 34 @ XAXIS 85 @ XAXIS
    136 @ XAXIS 187 @ XAXIS 238
230 YAXIS 0 @ YAXIS 128 @ YAXIS
    255
240 MOVE 0,245
250 FOR X=1 TO 255
260 Y=NUM(Y$[X])
270 PENUP
280 PLOT X,Y
290 NEXT X
300 END
```

- 200 GCLEAR, 210 SCALE, 220 XAXIS, 230 YAXIS: Clear graphics store; Enter the minimum/maximum values; Display CRT screen raster
- 240 MOVE through 280 PLOT X,Y: Transfer the "y" value from Y$ storage and plot for x = 1 to 255

Figure 3-41 shows the measured result taken from the RME-5 and plotted in Fig. 3-39.

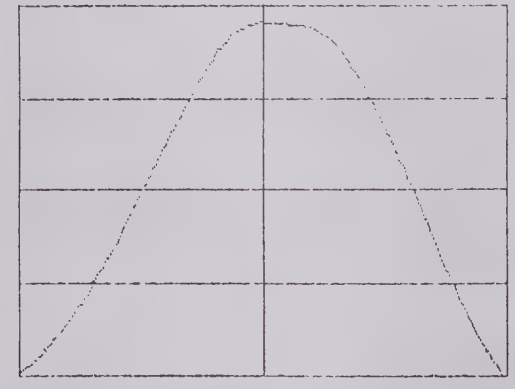


Fig. 3-41 Example of the measuring curve presented by the computer

3.11.2.7 Checking word "CO,"

In answer to the checking word "CO,", the RME-5 transfers a status byte[1)] to the control unit. After the ISO-7 bit code has been recalculated into a 16 place binary number, the bit position B_i can be interpreted after the omission of bytes "B_7 to B_0" as shown in the following:

1) not to be misunderstood as the status byte that is employed in a serial poll request like in the program of example B in para. 3.11.2.6!

CHECKING WORD	C		,
Format: B_7 B_6 B_5 B_4 B_3 B_2 B_1 B_0		0	

Bit-position	Signal	Bit position status Ø	1
B_7	AFC	not captured	captured
B_6	U_X synchronization	no synchronized	synchronized
B_5	IF level	out of range	correct level
B_4	BB level[2)]	out of range	correct level
B_3	IF level, P_I	out of range	in range
B_2	Test frequency deviation Δf	out of range	in range
B_1	BB level[3)]	out of range	in range
B_0	Test frequency, f_M	not detected	detected

The following example of programming shows the interrogation of the checking byte as an example of the distortion measurement according to Fig. 3-39.

```
10 DIM A$[16],B$[16]
20 OUTPUT 705 USING "K" ; "CO,"
30 ENTER 705 USING "%,W" ;A
40 A$=DTB$(A)
50 B$=A$[9,16]
60 DISP B$
70 END

11111101
```

Prepare storage areas
Send checking word
Transfer into store A
Recalculation into binary word
Extinguish bytes "B_7 to B_0"
Checking byte displayed

The above illustrated checking byte shows that all measuring conditions are correct. [B_1 (= 0) is insignificant in distortion measurements].

3.11.3 INITIALIZING

3.11.3.1 Basic initialization 1, (IF mode)

After <IEC 625> BUS instruction, "Device Clear" and, if needed, "Interface Clear" the operating mode is setup at the RME-5, as though the following programming word has been received from the control unit; i.e. "IN1,".

The programming word, "IN1,", contains the following individual instructions (programming words).

---

2) "Distortion Measurement" mode signal at connector [27]

3) "BB Level Measurement" mode signal at connector [29]

	"IN1,"
IF7Ø	70 MHz IF frequency input
IIF	IF signal inputs [25] and [26] are active
UXIF	Phase U_X out of IF
AUTR1	Autoranging "ON"
Y11	Mode result 1 "ON"
Y21	Mode result 2 "ON"
DP	Mode "$\Delta\tau, \Delta\varphi$"
P12	Mode "ΔP_I"
R14	Measuring range for result 1, dependent on f_M
R24	Measuring range for result 2 = 0.4 dB/div
SLØ	Slope correction "OFF"
AV2	Noise averaging factor "4"

No other functions are in operation!

3.11.3.2 Initial setup for BB mode

The programming word "IN2," comprises the following individual instructions.

	"IN2,"
IF7Ø	70 MHz IF frequency input
IBF	BB input signal, connector [27] is activ
UXBF	Phase U_X out BB
AUTR1	Autoranging "ON"
Y11	Mode result 1 "ON"
Y21	Mode result 2 "ON"
DP	Mode "$\Delta\tau, \Delta\varphi$"
DG	Mode "$\Delta U/U_o$"
R14	Measuring range for result 1, dependent on f_M
R24	Measuring range for result 2: 1%/div
SLØ	ΔP_I slope correction "OFF"
AV2	Noise averaging factor "4"

All other functions are "OFF".

3.11.4 PROGRAMMING WORDS FOR SETTING-UP THE RME-5

3.11.4.1 Programming words for setting-up the operating modes, and the measuring modes, and for evaluating the distortion curves

PROGRAMMING WORD	FUNCTION	
IN1,	"Initial setup" 1	IF mode see 3.11.3.1
IN2,	"Initial setup" 2	BB mode see 3.11.3.2
IF7Ø,	"IF input frequency"	70 MHz
IF35,	"IF input frequency"	35 MHz
IIF,	"IF signal input",	Connector [25], [26]
IBF,	"BB signal input",	Connector [27]
Y1Ø,	"Mode result 1" "OFF"	(Push button function [2] "ON/OFF"
Y11,	"Mode result 1" "ON"	(Push button function [2] "ON/OFF"
Y2Ø,	"Mode result 2" "OFF"	(Push button function [10] "ON/OFF"
Y21,	"Mode result 2" "ON"	(Push button function [10] "ON/OFF"
P11,	Mode ΔP_I, result 1	(Push button function [2])
P21,	ΔP_{II}, result 1	(Push button function [2])
P12,	ΔP_I, result 2	(Push button function [10])
P22,	ΔP_{II}, result 2	(Push button function [10])
DP,	Modes "$\Delta\tau$, $\Delta\varphi$", result 1	([2])
DG,	"$\Delta U/U_o$", result 2	([10])
EX1,	Mode Y_{ext}, result 1	([2])
EX2,	Y_{ext}, result 2	([10])
R11, to R17,	Measuring range result 1 ([2])	see para 3.11.4.2
R21, to R27,	Measuring range result 2 ([10])	see para 3.11.4.2
UXIF,	Phase U_X out of IF	
UXBF,	Phase U_X out of BB	

PROGRAMMING WORD	FUNCTION
FBØ, FB1,	Forw. and Backw. display "OFF" Forw. and Backw. display "ON" } (Tastenfunktion [17])
HLOFF, HL␣␣␣␣ ⌃⌄	"Horizontal lines" "OFF" "ON", ⌃⌄ : Line separation (see 3.11.2.3, example C)
BWØ, BW1,	"300" Hz filter" "OFF" "ON" } (Push button function [7])
SLØ, SL1,	"ΔP_I-slope correction "OFF" "ON"
AUTRØ, AUTR1,	Autoranging "OFF" "ON" } (Push button function [30]
AV␣ n	"AVERAGING" n = 0: switched off n = 1, 2, 3, 4, 5: on, averaging factors 2, 4, 8, 16, 32
LPØ, LP1,	"Curve analysis" LIN/PARAB: "OFF" LIN/PARAB: "ON"
NOFF, NDIF, NREF, NSTO,	"NORMALIZER" - function switched OFF - curve difference presentation - reference result presentation - reference result storage
SR␣␣␣␣␣␣, A x_i y_i	"Reference curves input" (condition, Y result presentation "ON") A = detection of the reference curve (1 or 2) x_i = x value: ØØ1 to 255 y_i = y value coordinated with X_i
L␣␣L_____, n z	"Text input" n: line number (Ø1 to 13) (Maximum of 5 lines are superimposable) z: 30 alphanumeric characters per line are possible
ER, L␣␣, n	Erase complete character field Erase single line; n from Ø1 to 13

PROGRAMMING WORD	FUNCTION
	"Mode"
FØØ,	- IF counter: "OFF"
FØ1,	- IF counter: "ON"
BESØ,	- Bessel spectrum: "OFF"
BES1,	- Bessel spectrum: "ON"
BFLØ,	- BB level: "OFF"
BFL1,	- BB level: "ON"

3.11.4.2 Programming words for setting-up the RANGE

from type "Rij," i = 1 or 2, j = 1 to 7

MEASUREMENT MODE	*)	PROGRAMMING WORDS						
Under pushbutton row [2]		R11	R12	R13	R14	R15	R16	R17
Under pushbutton row [10]		R21	R22	R23	R24	R25	R26	R27
$\Delta\tau$ (% rad/D)	"R1j,"	0.1	0.25	0.5	1	2.5	5	10
$\Delta\varphi$ (ns/D) 27.7/25 kHz		4	10	20	40	100	200	400
55.5/50 kHz		2	5	10	20	50	100	200
92.6/83.3 kHz	"R1j,"	1	2.5	5	10	25	50	100
277.7/250 kHz		0.4	1	2	4	10	20	40
555.5/500 kHz		0.2	0.5	1	2	5	10	20
$\Delta U/U_o$ (%/D)	"R2j,"	0.1	0.25	0.5	1	2.5	5	10
ΔP_I (dB/D)	"Rij",	-	0.1	0.2	0.4	1	2	4
ΔP_{II} (dB/D)	"Rij,"	-	-	2	4	10	20	-
Y_{EXT} (mV/D)	"Rij,"	2	5	10	20	50	100	200

*) i = 1 signifies result 1; corresponds to mode under pushbutton row [2]
i = 2 is correspondingly for result 2 (pushbutton row [10])

3.11.4.3 Programming words for setting-up the "Interface mode"

INTERFACE MODE	XX [1]						,
SERVICE REQUEST after "POWER ON"	NO	Ø					
	YES	1					
SERVICE REQUEST after execution of trigger function	NO		Ø				
	YES		1				
PARITY BIT: (In case of ISO-7 bit-Code)	No parity			Ø			
	Odd parity			1			
	Even parity			2			
END CHARACTER (In case of ISO-7 bit-Code)	No end character				Ø		
	END & DATA BYTE				1		
	END & ETX				2		
	ETX				3		
END CHARACTER (In case of no ISO-7-bit code)	No end character					Ø	
	END & DATA BYTE					1	
	END & ETX					2	

3.11.4.4 Programming word "Trigger mode"

TRIGGER MODE	T		,
Free-running (continuous)		Ø	
Trigger request (single)		1	

Note: usually "single trigger" mode should be used: "T 1 ,"

1) Instead of XX, @ can also be used

3.11.5 PROGRAMMING WORDS FOR ENTERING THE MEASURED RESULTS

3.11.5.1 Programming words for entering the "static measured results"

MEASURED RESULTS	NUMBER OF CHARACTERS [1]	PROGRAMMING WORD					
		RE					,
Test frequency f_M	4		Ø	Ø	insignificant		
Test frequency deviation Δf	3		Ø	1			
IF level P_I	6		Ø	2			
IF center frequency F_o	5		Ø	3			
Sweep width ΔF	4		Ø	4			
Frequency markers M	4		Ø	5			
F_o (IF counter operation)	6		Ø	6			
BB level	6		Ø	7			
Horizontal lines "$\hat{}$"	4		Ø	8			
LIN/PARAB component	10		Ø	9			
Extreme values Curve 1	12		Ø	A			
Curve 2	12		Ø	B			

3.11.5.2 Programming words for transferring "dynamic measured results"

MEASURED RESULTS	PROGRAMMING WORD					
	RE					,
Y1 Result "Single point"		1	X_2	X_1	X_0	
Y2 Result		2	X_2	X_1	X_0	
Y1 Result "Complete curve"		1	Ø	Ø	Ø	
Y2 Result		2	Ø	Ø	Ø	

Single point requests: x-position of the Y result:

$X_2 = 10^2$-position

$X_1 = 10^1$-position

$X_0 = 10^0$-position

Definition range for x: ØØ1 to 255

3.11.6 RESULTS OUTPUT FORMAT

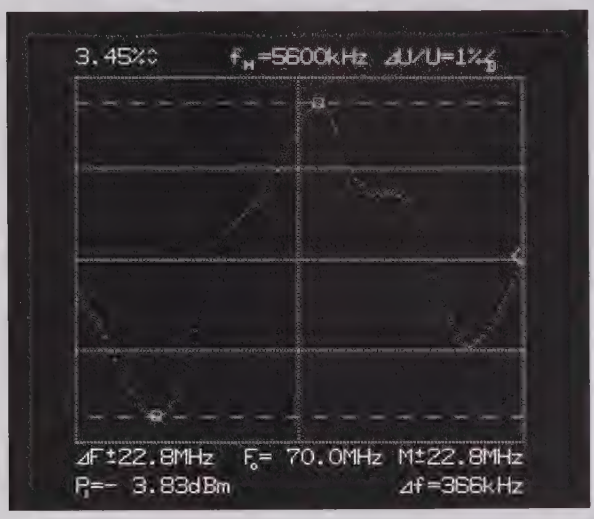
The output data are pure numeric; perhaps with signs and decimal points!

MEASURED RESULT	FORMAT	CONDITIONS, UNIT
Test frequency "f_M"	☐☐☐.☐	with f_M = 25/50/83.3 kHz or 27.7/55.5/92.6 kHz
	☐☐☐☐	with f_M = 250/500 kHz or 277.7/555.5 kHz
	☐☐☐☐	with f_M = 2400/5600 kHz
R.M.S. test freq. deviation "Δf"	☐☐☐	in kHz
IF level P_I	±☐☐.☐☐	in dBm
IF center frequency	☐☐☐.☐	in MHz
Sweep width "ΔF"	☐.☐☐	in MHz, F < 10 MHz
	☐☐.☐	in MHz, F ≥ 10 MHz
Frequency markers M	☐.☐☐	in MHz, F < 10 MHz
	☐☐.☐	in MHz, F ≥ 10 MHz
F_o (IF counter operation)	☐☐☐.☐☐	in MHz
BB level	±☐☐.☐☐	in dBm
Horizontal lines "◊"	.☐☐☐	Dependent upon measuring range
	☐.☐☐	
	☐☐.☐	
	☐☐☐.	
LIN/PARAB components	☐☐☐☐☐☐☐☐☐☐ LIN component | Space PARAB component	Dependent upon measuring range
Extreme values	☐☐☐☐☐☐☐☐☐☐ X_{Min} Y_{Min} X_{Max} Y_{Max}	see Example II in 3.11.7

3.11.7 EXAMPLES OF RME-5 UNDER REMOTE CONTROL

The programs refer to the HP-85 Desktop Computer.

3.11.7.1 Absolute distortion, evaluation of the extreme values



□ = P_1

□ = P_2

Fig. 3-42 Example of the distortion curve "$\Delta U/U_o$" with the extreme values, P_1 and P_2

The programming word,"REØB", for requesting the extreme values of result 2, permits the calculation of the absolute distortion according to the relationsship described in para. 3.11.2.6.

```
 10 RESET 7
 20 OUTPUT 705 ;"@01011,T1,"
 30 OUTPUT 705 ;"Y10,DG,R24,AV5,
    "
 40 OUTPUT 705 USING "K" ; "RE0B
    ,"
 50 TRIGGER 705
 60 ON INTR 7 GOTO 80
 70 ENABLE INTR 7;8
 80 STATUS 7,1 ; S
 90 IF S=8 THEN GOTO 70
100 ENTER 705 USING "%,%K" ; B$
110 C$=B$[4,6]
120 D$=B$[10,12]
130 C=VAL(C$)
140 D=VAL(D$)
150 Y=(D-C)/51*1
160 DISP USING 170 ; Y
170 IMAGE ZZ.DD
180 END
```

Line 10: reset RME-5 to initial setup (IN1)

Line 20: set interface mode and trigger mode

Line 30: set RME-5 to wanted setup - programming words according to 3.11.4; compare monitor display with Fig. 3-42.

Line 40: send result mode "REØB," to RME-5.

Lines 50
to 90: send trigger instruction; execute single measurement with end of program identification, "SRQ"

Line 100: enter result, B$

Line 110: form C$: mask the y_{Min} value

Line 120: form D$: mask the y_{Max} value

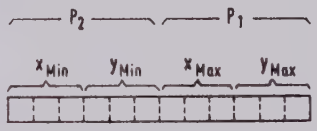
Lines 130
and 140: convert string into numerical result

Line 150: calculation of the absolute value, y, (51 = Δy; 1 $\widetilde{=}$ range 1%/D)

Lines 160
and 170: display and formatting of y value

Line 180: end of program

The current string printout in single items:




```
DISP B$
047047136224 ———— output data, B$, 12 characters:
DISP C$
047 ———————————— ymin ≅ y value of P2, see Fig. 3-41
DISP D$
224 ———————————— ymax ≅ y value of P1, see Fig. 3-41

03.45 ———————————— calculated distortion value
```

3.11.7.2 Storing and calling-up a reference curve, magnetic tape

a) Store reference curve on tape in cassette:

The distortion result according to Fig. 3-42, besides the setup parameters like mode and range and so on, shall be stored on magnetic tape in a cassette.

Preparation: setup the data file "Ref Cur" with 2 records; sufficient for a result curve (256 bytes) with setup parameters.

Entry: CREATE "RefCur" , 2

Program:

```
 10 DIM Y$[255],O$[50],Y(255)
 20 RESET 7
 30 OUTPUT 705 ;"@01011,T1,"
 40 O$="Y10,DG,R24,AV5,"
 50 OUTPUT 705 USING "K" ; O$
 60 TRIGGER 705
 70 OUTPUT 705 USING "K" ; "RE20
    00,"
 80 TRIGGER 705
 90 ON INTR 7 GOTO 110
100 ENABLE INTR 7;8
110 STATUS 7,1 ; S
120 IF S#8 THEN 120
130 ENTER 705 USING "%,%K" ; Y$
140 OUTPUT 705 USING "K" ; "T0,"
150 FOR I=1 TO 255
160 Y(I)=NUM(Y$[I])
170 NEXT I
180 !
190 ASSIGN# 1 TO "RefCur"
200 PRINT# 1 ; O$,Y()
210 ASSIGN# 1 TO *
220 DISP "Curve 2 stored on Cass
    ette !"
230 END
```

Line 10: prepare store: - for entry of result curve in Y$ and
- for recalculation into numerical characters (Y)
- for transfer of the setup parameter (O$)

Line 20: reset RME-5 to basic setup

Line 30: set interface mode and trigger mode

Line 40: form string for the setup parameters

Lines 50 and 60: set RME-5 to wanted setup.

Line 70: instruction for request to curve 2: "RE2ØØ,"

Line 80 to 140: enter the y values; refer to Example B, "Entry of the complete curve, see 3.11.2.6 (lines 40 to 100)

Line 150: I corresponds to the x positions "ØØ1 to 255"

Line 160: Conversion of string printout to numbers (y values of curve)

Line 170: Call-up next X position

Line 190: opening the "Ref Cur" data file

Line 200: serial storage of setup data (O$) and the reference curve (Y ())

Line 210: terminate the data file

Line 220: end of program identification, (prgram runs for about 60 s)

Line 230: end of program

b) Load reference curve from cassette into reference curve store of RME-5

In order to load into the RME-5 the curve stored in a cassette as described in a) the store for the "Reference Curve" of the NORMALIZER function (see section 3.7.2) is allocated to be the storage cell. With manual operation the push button function "DISP (REF)" is used to call-up the curve. The following program is executed, and in practice this program section is attached to the program displayed under a); that is commencing with line 230.

Program:

```
 10 DIM O$[50],Y(255)
 20 OUTPUT 705 ;"@01011,T1,"
 30 ASSIGN# 1 TO "RefCur"
 40 READ# 1 ; O$,Y()
 50 ASSIGN# 1 TO *
 60 !
 70 OUTPUT 705 USING "K" ; O$
 80 TRIGGER 705
 90 FOR I=1 TO 255
100 OUTPUT 705 USING "3A,3Z,3Z,A
    ," ; "SR2",I,Y(I),","
110 NEXT I
120 TRIGGER 705
130 !
140 OUTPUT 705 USING "K" ; "NREF
    ,T0,"
150 TRIGGER 705
160 DISP "Curve loaded in REF-Me
    mory(RME-5) !"
170 END
```

Line 10: prepare store for entry of curve and setup parameters

Line 20: set interface mode and trigger mode

Line 30: open the "Ref Cur" data file

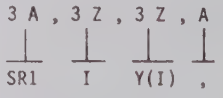
Line 40: read-out the string (O$) and array values (Y ()).

Line 50: terminate the data file

Lines 70 and 80: output string for setting up instrument and send trigger mode

Line 90: x positions ØØ1 to 255

Line 100: from output string; formatting:



program word:

Line 110: call-up the next x position

Line 120: send trigger instruction

Lines 140 and 150: setup reference curve of RME-5, (LED "REF" under row of push buttons [12] is ON)

Line 160: end of program identification, (program runs for about 80 s)

4 MEASURING NOTES

4.1 OCCURENCE OF DISTORTION IN FM RADIO-LINK SYSTEMS AND INTERPRETATION OF THE RESULTS $\Delta\tau$; $\Delta\varphi$ AND $\Delta U/U_o$

The intermodulation noise measured at the BB output of a radio-link system with a white noise measuring setup increases as the power level in the system is raised. This increase is caused by the linear and non-linear distortions within the assemblies. The most important of these are:

- non-linear relationship between voltage and frequency in modulators and demodulators;
- amplitude frequency response within the transmission band for the FM signal;
- non-linear phase response within the transmission band for the FM signal;
- AM/PM conversion in IF limiters and travelling wave tubes;
- incorrectly matched, long transmission lines for the FM signal;
- distortion in the baseband amplifiers.

A disadvantage of the the white noise measuring method is that the result provides little information on which of the distortions has caused the noise. Generally, several sources are responsible for the resulting noise. Precise analysis of the distortion is possible only with a distortion measuring setup such as the RM-5. The measuring method used is the intermodulation method which is used generally in radio-link measuring technology, and whose principle is described in Section 2.1.

The following questions are important for interpretation of the distortion measurement results displayed on the screen of the measuring setup:

- Is this an amplitude or phase measurement result?
- At which measuring frequency, in operating mode "automatic sweep width reduction", are the distortions maximum?
- Is there a relationship between the measuring frequency and the result?
- What is the shape of the result?

If these four questions can be answered clearly, then there are only a few possible causes of the interference. In order to permit the user of the RM-5 to answer the questions, the following sections deal with the various causes of interference and effects on the measured results. In order to simplify comprehension of these sections, the origins of most of the formulas used have been omitted. For further information, see the W&G special brochure written by
R. Dick: "Detection of faults in the transmission pathof FM signals with the aid of modern distortion measuring equipment", Order No. 5022.

4.1.1 DISTORTIONS RESULTING FROM NON-LINEARITIES IN MODULATORS AND DEMODULATORS

If the characteristic curve of a frequency modulator or demodulator is not straight, i.e. has variations in the slope, then the signal at the receiving end will be amplitude modulated by the deflection frequency. Display of the demodulated signal on an oscilloscope will lead to various results for the linearity distortion $\Delta U/U_o$, depending on the shape of the characteristic curve.

A square law characteristic ($\Delta f = au + bu^2$) leads to a tilted straight line on the screen of the receiver, while a cube law characteristic ($\Delta f = au + cu^3$) will result in a parabolic curve. If square law and cube law distortions occur simultaneously, the components can be displayed separately on the screen:

one component "LIN" describes the "slope" of the curve, and a second component "PARAB" indicates the "bending"of the curve (see Section 3.7.3)

The relationship between the shape of the characteristic curve and the shape of the curve on the screen is shown in Figure 4-1.

As modulator and demodulator characteristic curves are generally independent of frequency, the displayed linearity distortions $\Delta U/U_o$ are also independent of the test frequency used. It is therefore sufficient to measure with only one test frequency $f_M < 1$ MHz for measurements on modulators and demodulators.

4.1.2 DISTORTION IN THE TRANSMISSION PATH OF THE FM SIGNAL

In the transmission of the FM signal (IF or RF level), distortion is caused both by amplitude and group delay frequency responses and by AM/PM conversion.

The cause of the distortion can be determined from the type ($\Delta\tau$ or $\Delta\varphi$ or $\Delta U/U_o$), shape, and variation with test frequency of the results displayed on the screen of the RM-5.

The transmission factor for transmission two port networks generally used in practical applications (in this case: path of the FM signal) $H(\Omega) = A(\Omega) \cdot e^{jb(\Omega)}$ can be approximated by a series expansion:

$$H(\Omega) = [1 + g_1 (\Omega - \Omega_o) + g_2 (\Omega - \Omega_o)^2 + g_3 (\Omega - \Omega_o)^3 + g_4 (\Omega - \Omega_o)^4 + \ldots.] \times \exp.\, j\, [b_2 (\Omega - \Omega_o)^2 + b_3 (\Omega - \Omega_o)^3 + b_4 (\Omega - \Omega_o)^4 + \ldots]$$

In the development of this series, the linear element b_1 was suppressed, as this indicates only a group delay and causes no distortion.

The transmission two port network is supplied with an angular modulated signal, whose amplitude is normalized to the carrier voltage in order to simplify consideration:

$$u_e(t) = \cos [\Omega_o t + \Phi(t)]$$

Ω_o is the carrier frequency and $\Phi(t)$ is the phase angle; taken together as containing the information.

After the signal has passed through the transmission two port network, there is generally an additional amplitude modulation P(t) and a phase modulation Q(t), which means that the signal can now be represented as:

$$u_a(t) = [1 + P(t)] \cos [\Omega_o t + \Phi(t) + Q(t)]$$

Limiters in the FM signal path are generally designed to suppress frequency-dependent interference AM P(t). This requirement can be fulfilled only with difficulty, as both the travelling wave tube limiter and the limiter preceding the FM demodulator convert a part of the amplitude modulation into additional interference PM $Q_z(t)$. The relationship is given by the AM/PM conversion factor Θ:

$$Q_z(t) = \Theta P(t)$$

Θ is normally also frequency dependent and can be described approximately by a series expansion:

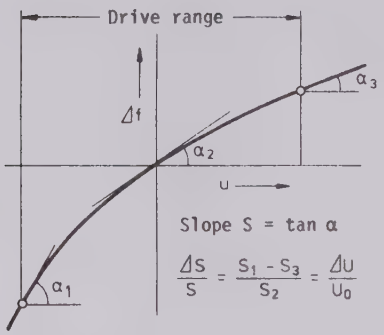
$$\Theta(\Omega) = \Theta_0 + \Theta_1 (\Omega - \Omega_0) + \Theta_2 (\Omega - \Omega_0)^2 + \ldots$$

The additional interference PM $Q_z(t)$ is then

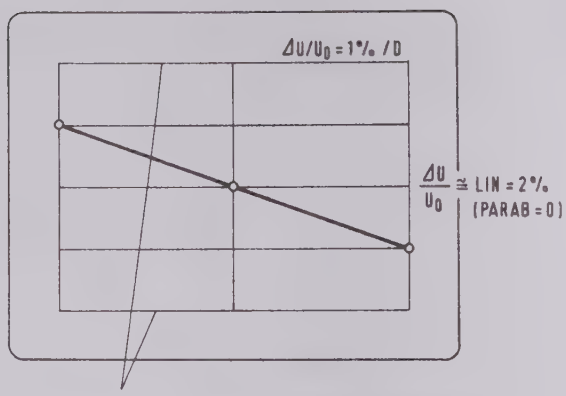
$$Q_z(t) = \Theta_0 P(t) + \Theta_1 P(t) \Phi'(t) + \Theta_2 P(t) \Phi'^2(t)$$

Modulator characteristic

Square law

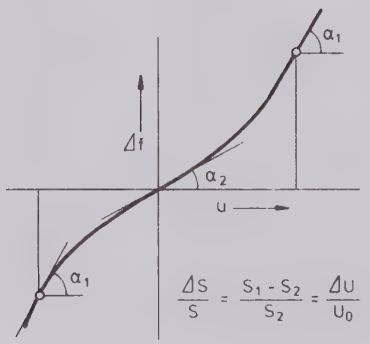


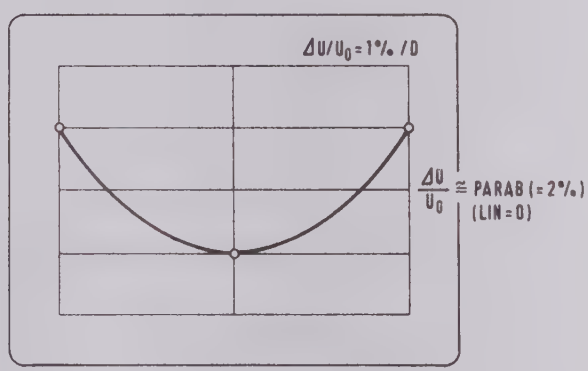
Measuring mode $\Delta U/U_0$ on screen



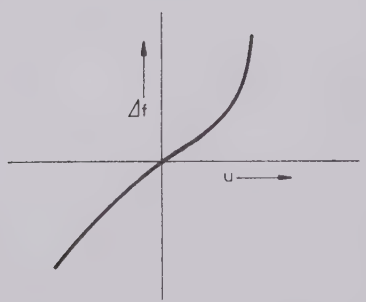
Calibration lines for full measuring range

Cube law





General case



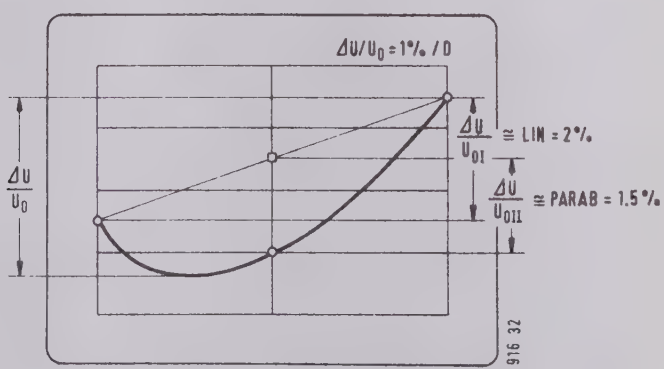


Figure 4-1 Linearity distortion $\Delta U/U_0$ on the screen as a function of modulator characteristic curves

The signal before passing through the FM demodulator has the following shape if the AM/PM conversion is included:

$$u_a(t) = \cos [\Omega_o t + \Phi(t) + Q(t) + Q_z(t)]$$

Tables 4-1 and 4-2 show the distortion measurement results for the important causes of impairments with respect to resulting intermodulation noise. In the calculation, the results of coefficients g_1, g_2, g_3, g_4 and b_2, b_3, b_4 were included. The effects of AM/PM conversion were assumed to be both frequency independent (Θ_0) and varying linearly with frequency (Θ_1).

Cause of interference		Phase measurement results $\Delta\varphi$			
		General	With constant sweep range $\pm \Delta\Omega_A$		
		$\Delta\varphi$	$\omega_{M\,opt}$	$\Delta\varphi_{max}$	Form
Parabolic phase	b_2	$4b_2 \Delta\Omega\omega_M$	$1/2\ \Delta\Omega_A$	$b_2 \Delta\Omega_A^2$	
Cubic phase	b_3	$3b_3 \Delta\Omega^2 \omega_M$	$1/3\ \Delta\Omega_A$	$4/9\ b_3 \Delta\Omega_A^3$	
Quadratic phase	b_4	$8b_4 (\Delta\Omega\omega_M^3 + \Delta\Omega^3\omega_M)$	$1/2\ \Delta\Omega_A$	$b_4 \Delta\Omega_A^4$	
AM/PM conversion	$g_1\ \Theta_1$	$4g_1\Theta_1 \Delta\Omega\omega_M$	$1/2\ \Delta\Omega_A$	$g_1\Theta_1\Delta\Omega_A^2$	
	$g_2\ \Theta_0$	$4g_2\Theta_0 \Delta\Omega\omega_M$	$1/2\ \Delta\Omega_A$	$g_2\Theta_0\Delta\Omega_A^2$	
	$g_3\ \Theta_0$	$3g_3\Theta_0 \Delta\Omega^2\omega_M$	$1/3\ \Delta\Omega_A$	$4/9\ g_3\Theta_0\Delta\Omega_A^3$	
	$g_4\ \Theta_0$	$8g_4\Theta_0 (\Delta\Omega\omega_M^3 + \Delta\Omega^3\omega_M)$	$1/2\ \Delta\Omega_A$	$g_4\Theta_0\Delta\Omega_A^4$	

07 916

Table 4-1 Phase measurement results as a function of cause of impairments

Cause of interference		Amplitude results $\frac{\Delta U}{U_0}$			
		General	With constant sweep range $\pm \Delta\Omega_A$		
		$\frac{\Delta U}{U_0}$	$\omega_{M\,opt}$	$(\frac{\Delta U}{U_0})_{max}$	Form
Parabolic phase	g_2	$g_2^2 \Delta\Omega^2 \omega_M^2$	$1/2\ \Delta\Omega_A$	$\frac{g_2^2}{16}\ \Delta\Omega_A^2$	
Cubic phase	g_3	$6 g_3 \Delta\Omega\, \omega_M^2$	$2/3\ \Delta\Omega_A$	$8/9\ g_3 \Delta\Omega_A^3$	
Quadratic phase	g_4	$6 g_4 \Delta\Omega^2 \omega_M^2$	$1/2\ \Delta\Omega_A$	$3/8\ g_4 \Delta\Omega_A^4$	
AM/PM conversion	$b_2\Theta_1$	$2 b_2 \Theta_1 \Delta\Omega\, \omega_M^2$	$2/3\ \Delta\Omega_A$	$8/27\ b_2\Theta_1 \Delta\Omega_A^3$	
	$b_3\Theta_0$	$6 b_3 \Theta_0 \Delta\Omega\, \omega_M^2$	$2/3\ \Delta\Omega_A$	$8/9\ b_3\Theta_0 \Delta\Omega_A^3$	
	$b_4\Theta_0$	$6 b_4 \Theta_0 \Delta\Omega^2 \omega_M^2$	$1/2\ \Delta\Omega_A$	$3/8\ b_4\Theta_0 \Delta\Omega_A^4$	

916.49

Table 4-2 Amplitude measurement results as a function of cause of impairments

Area shapes of measured results occur depending on the cause of impairment. These are sketched in tables 4-1 and 4-2, in each case for positive g_n, b_n and Θ.

The type of measured result which occurs - phase or amplitude measurement result - is a further indication of the cause of the impairment.

The measured results shown in the general form also show a dependency on the selected test frequency ω_M.

For example, the amplitude measurement result increases as a square of the test frequency for coefficient g_3. Due to the finite bandwidth of the transmission path, however, limits exist.

If the operating mode "automatic sweep width reduction" is used, i.e. if fixed sweep limits of $(\Delta\Omega_A = \Delta\Omega + \omega_M)$[1] are specified, then $\Delta\Omega$ in the general form of the results can be replaced by $(\Delta\Omega_A - \omega_M)$. It is now obvious that small results must be expected for low test frequencies and that the result becomes 0 when $\omega_M = \Delta\Omega_A$.

The optimum test frequency lies between these values. It is found by differentiating the general form of the measured result, modified with $(\Delta\Omega_A - \omega_M)$ instead of $\Delta\Omega$, on the basis of ω_M, setting equal to zero and resolving for ω_M.

For example, Table 4-2 shows that the optimum test frequency $\omega_{M,opt} = 2/3\ \Delta\Omega_A$ for the cubic gain g_3

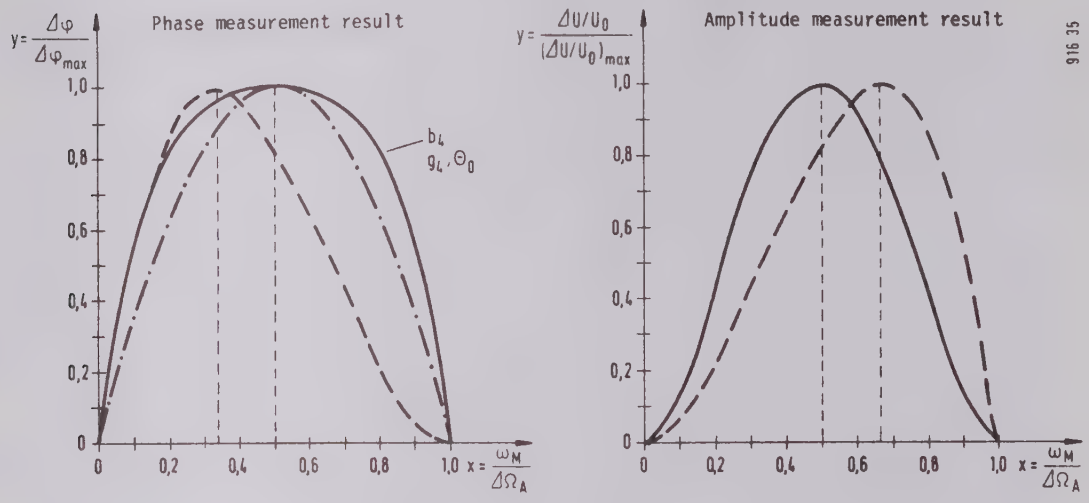
In a further step, the maximum result can be calculated if the optimum test frequency is inserted in the general form of the result for ω_M. In the selected example with g_3, the maximum amplitude measurement results $\Delta U/U_0 = 8/9\ g_3 \Delta\Omega_A^3$.

The values for the optimum measuring frequencies in the operating mode "automatic sweep width reduction" (constant exploring width) show that many causes of impairments can be detected only if high test frequencies are used.

1) $\Delta\Omega_A = \Delta\Omega + \omega_M$ means $\Delta\hat{F} = \Delta\hat{F}_{RED} + f_M$

Depending on the exponents in the frequency product $\Delta\Omega^m \omega_M{}^n$, which occurs in all results, characteristic sensitivity curves for the measured results as a function of the test frequency will result. The sensitivity curves are shown in Figure 4-2.

For evaluation, the measured results $\Delta\tau$ or $\Delta\varphi$ and $\Delta U/U_o$ are first measured at all available test frequencies and the curve is recorded. After this, the causes of impairments are determined with the aid of Table 4-1 and 4-2, this being explained with the aid of the following example:



x_{opt}	Cause of interference with resulting shape:		
	Straight	Parabolic	
		Quadr.	Cubic
1/3		b_3 g_3, Θ_0	
1/2	b_2 g_1, Θ_1 g_2, Θ_0		b_4 g_4, Θ_0

x_{opt}	Cause of interference with resulting shape:	
	Straight	Parabolic
1/2	g_2	g_4 b_4, Θ_0
2/3	g_3 b_2, Θ_1 b_3, Θ_0	

Figure 4-2 Relative measuring sensitivity as a function of the test frequency referred to the exploring range ($x = \omega_M/\Delta\Omega_A$, $y = \Delta U/U_o/(\Delta U/U_o)_{max}$ or $y = \Delta\varphi/\Delta\varphi_{max.}$)
In the tables: corresponding causes of impairments

In practical applications, the results shown in Tables 4-1 and 4-2 will generally not appear in such a pure form. However, interpretation is possible in most cases.

If a $\Delta U/U_o$ result with $\omega_{M,opt.} = 2/3\,\Delta\Omega_A$ occurs, and if the shape is a straight line, then the cause of the impairment can, on the basis of Table 4-2, be g_3, $b_2\,\Theta_1$ or $b_3\,\Theta_o$.
If AM/PM conversion also occurs, then this can be detected clearly on the basis of the characteristic results for b_2 or b_3. If none of the expected $\Delta\varphi$ results occur, then the cause of the impairment must be g_3.

4.2 The "Bessel Spectrum"

In order to permit better understanding of the operating principle of the RM-5, in particular the operating mode "BESSEL SPECTRUM ▽" – pushbutton [3] of the RME-5, the basic principles of frequency modulation must first be briefly described. The theoretical basis of this description can be found in the brochure "Distortion Measuring Technology on Radio Relay Links" by H. Gommlich (W&G, Order No. 6134).

4.2.1 Frequency modulation

Radio-relay systems generally use frequency modulation, which is a special form of angle modulation. The general formula for an angle-modulated signal is

$$u(t) = \hat{U}\sin\psi(t).$$

For angle modulation, the argument $\psi(t)$ is varied in the rhythm of the modulation signal, which means that the above equation can be rewritten, with the carrier frequency Ω_T and varying phase $\Phi(t)$, as

$$u(t) = \hat{U}\sin\psi(t) = \hat{U}\sin[\Omega_T t - \Phi(t)] \quad (1)$$

where the information is "hidden" in $\Phi(t)$.

If a sinusoidal modulation signal

$$u_1(t) = \hat{U}_1\cos(\omega_1 t + \varphi_1)$$

is used, then $\Phi(t) = \eta\cos(\omega_1 t + \varphi_1)$. The variation of the angle with time is then

$$\psi(t) = \Omega_T t - \eta\cos(\omega_1 t + \varphi_1). \quad (2)$$

A measure for the magnitude of the phase variation is the phase deviation η, also called the *modulation index*. As a variation of the angle ψ with time naturally causes a frequency change, then the instantaneous frequency is

$$\frac{d\psi(t)}{dt} = \Omega_T + \eta\omega_1\sin(\omega_1 t + \varphi_1) = \Omega_T + 2\pi\hat{\Delta f}\sin(\omega_1 t + \varphi_1).$$

The frequency deviation $\hat{\Delta f}$ is a measure for the frequency deviation. This can be calculated, from $\eta\omega_1 = 2\pi\hat{\Delta f}$, as

$$\hat{\Delta f} = \eta \cdot f_1. \quad (3)$$

The phase deviation or modulation index is thus

$$\eta = \frac{\hat{\Delta f}}{f_1}. \quad (4)$$

These relationships apply to frequency and phase modulation. The only differences between the two types of modulation are the following:

- If the frequency deviation $\hat{\Delta f}$ is proportional to the amplitude of the modulating signal, then the process is called frequency modulation (FM). The phase deviation η then varies, as shown by equation (3) in inverse proportion to the modulating frequency f_1.
- If the phase deviation η varies proportionally with the amplitude of the modulating signal, then the process is called phase modulation (PM).

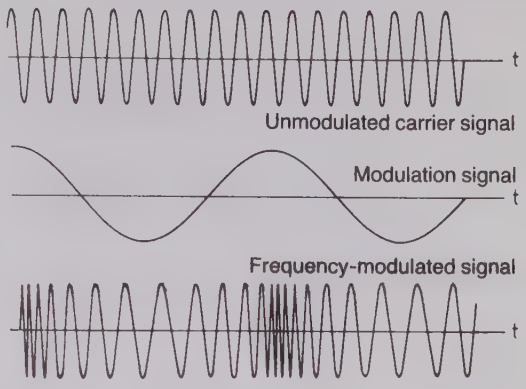


Figure I Frequency-modulated signal

Figure I shows the signal curve of a frequency-modulated signal.
The frequency spectrum of such a frequency-modulated signal with sinusoidal modulation is calculated below. First, it is necessary to obtain the exponential representation of the signal. For the general relationship

$$e^{jx} = \cos x + j\sin x$$

it is possible to write the imaginary part as

$$Jm\left\{e^{jx}\right\} = \sin x.$$

For the angle modulated signal in equation (1), the relationship is thus

$$u(t) = Jm\left\{U_T e^{j\psi(t)}\right\}.$$

If equation (2) is inserted in this equation, then

$$u(t) = Jm\left\{U_T e^{j[\Omega_T t - \eta\cos(\omega t + \omega_1)]}\right\}. \quad (5)$$

The Bessel functions with the order 0, 1, 2, 3, ... apply to the expression $e^{-j\eta\cos(\omega_1 t + \varphi_1)}$, which means that it can be represented as follows.

$$\begin{aligned} e^{-j\eta\cos(\omega_1 t + \varphi_1)} = J_0(\eta) &- 2jJ_1(\eta)\cos(\omega_1 t + \varphi_1) + \\ &+ 2j^2 J_2(\eta)\cos(2\omega_1 t + 2\varphi_1) - \\ &- + 2j^3 J_3(\eta)\cos(3\omega_1 t + 3\varphi_1) + \\ &+ \ldots\ldots \\ &- \ldots\ldots \end{aligned}$$

If this expression is then introduced into equation (5), the result is

$$\begin{aligned} u(t) = Jm\{&U_T(\cos\Omega_T t + j\sin\Omega_T)[J_0(\eta) \\ &- 2jJ_1(\eta)\cos(2\omega_1 t + \varphi_1) + \\ &+ 2j^2 J_2(\eta)\cos(2\omega_1 t + 2\varphi_1) - \\ &- 2j^3 J_3(\eta)\cos(3\omega_1 t + 3\varphi_1) + \\ &+ \ldots\ldots]\}. \end{aligned}$$

As only the imaginary parts must be considered, then

$$u(t) = U_T \{J_0(\eta)\sin \Omega_T t - 2J_1(\eta)\cos\Omega_T t \cdot \cos(\omega_1 t + \varphi_1) - 2J_2(\eta)\sin \Omega_T t \cdot \cos(2\omega_1 t + 2\varphi_1) - 2J_3(\eta)\cos \Omega_T t \cdot \cos(3\omega_1 t + 3\varphi_1) - \ldots\}. \quad (6)$$

With the aid of the general trigonometrical relationships

$$\cos\alpha \cdot \cos\beta = \frac{1}{2}[\cos(\alpha - \beta) + \cos(\alpha + \beta)]$$

$$\sin\alpha \cdot \cos\beta = \frac{1}{2}[\sin(\alpha - \beta) + \sin(\alpha + \beta)]$$

and

$$-\cos x = \sin\left(x - \frac{\pi}{2}\right)$$

$$-\sin x = \sin(x - \pi)$$

$$\cos x = \sin\left(x - \frac{3\pi}{2}\right)$$

it is possible to obtain the spectral composition of the frequency-modulated signal when modulated with the sinusoidal signal $\hat{U}_1\cos(\omega_1 t + \varphi_1)$.
The following is true for the FM signal

$$u(t) = U_T J_0(\eta)\sin \Omega_T t + U_T J_1(\eta)\left\{\sin[(\Omega_T + \omega_1)t + \varphi_1 - \frac{\pi}{2}] + \sin[(\Omega_T - \omega_1)t - \varphi_1 - \frac{\pi}{2}]\right\} + U_T J_2(\eta)\left\{\sin[(\Omega_T + 2\omega_1)t + 2\varphi_1 - \pi] + \sin[(\Omega_T - 2\omega_1)t - 2\varphi_1 - \pi]\right\} + U_T J_3(\eta)\left\{\sin[(\Omega_T + 3\omega_1)t + 3\varphi_1 - \frac{3\pi}{2}] + \sin[(\Omega_T - 3\omega_1)t - 3\omega_1 - \frac{3\pi}{2}]\right\} + \ldots. \quad (7)$$

The curve of the Bessel function $J_0(\eta)$, $J_1(\eta)$... for the amplitude of the carrier and of the sidebands is shown in Figure II.

With the aid of the formulas for the frequency-modulated signal [equation (7)], it is possible to derive the vector diagram for a frequency-modulated signal (Figure III). The vector diagram for four different instants in time with a phase deviation $\eta = 1 \triangleq 57.3°$ is shown in Figure IV. In Figures III and IV, the vectors of the carrier signal and of the sideband signals of the 1st and 2nd order are shown. The geometrical addition of these vectors results in a total vector (resultant vector) which moves over an arc of $\pm 57.3°$. The generation of this arc is understandable because the amplitude of an undistorted FM signal, as shown by Figure I, is constant. The radius of the arc is equal to the amplitude of the unmodulated carrier signal.

In contrast to amplitude modulation, the amplitude of the carrier varies in the case of frequency modulation. The carrier amplitude is 0 when the Bessel function $J_0(\eta) = 0$; this is the case (as can be seen from Figure II) at the phase deviations $\eta = 2.405, 5.520, 8.654$.

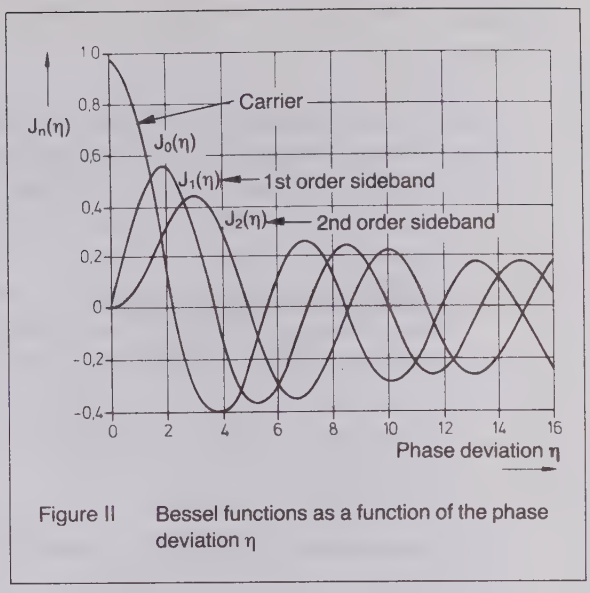


Figure II Bessel functions as a function of the phase deviation η

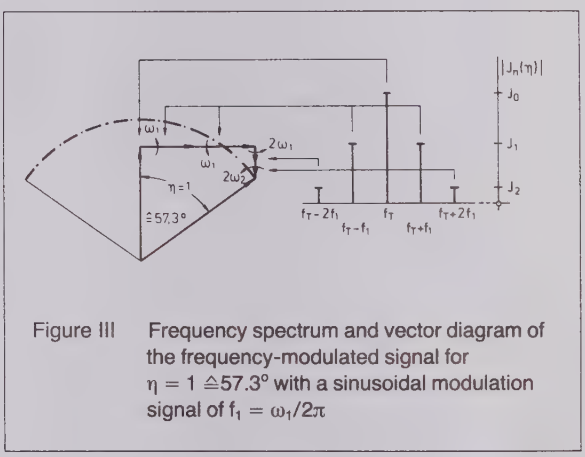


Figure III Frequency spectrum and vector diagram of the frequency-modulated signal for $\eta = 1 \triangleq 57.3°$ with a sinusoidal modulation signal of $f_1 = \omega_1/2\pi$

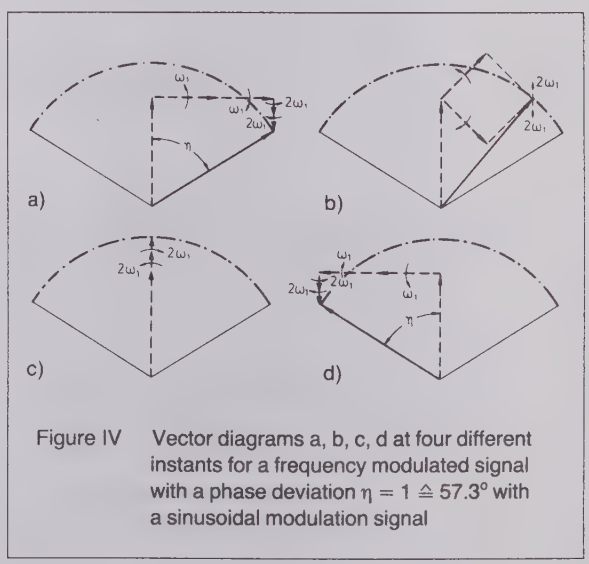


Figure IV Vector diagrams a, b, c, d at four different instants for a frequency modulated signal with a phase deviation $\eta = 1 \triangleq 57.3°$ with a sinusoidal modulation signal

4.2.2 BESSEL SPECTRUM AS A FUNCTION OF THE TEST FREQUENCY AND RMS VALUE TEST FREQUENCY DEVIATION

The frequency spectra which result from equation (4) for various phase deviations ($\eta \sim \Delta f \sim U_M$) are shown for three different test frequencies in Figure 4-3. It can be seen that the frequency spectrum becomes wider due to augmentation of higher order sidelines as the phase deviation increases.

In the operating mode "distortion measurement", where the complete FM spectrum is swept with the sweep frequency within the IF range (depending on the sweep width $\hat{\Delta F}$), the phase deviation η is always less than one, as only the carrier and the first sidelines are required.

For calibration of the r.m.s. value deviation meter, and for setting the slopes of modem units in the operating mode "Bessel spectrum", a phase deviation $\eta = 2.405$ (first Bessel null position) is set up:

$$\Delta f = 2.405 \cdot f_M = \hat{\Delta f}_0 \; ; \; (\hat{\Delta f} = \sqrt{2}\,\Delta f)$$

Disappearance of the carrier - "Bessel" - on the screen of the RME-5 is best seen at the test frequencies $f_M = 83.3$ kHz (or 92.6 kHz) and 250 kHz (or 277.8 kHz); see Figure 4-3.

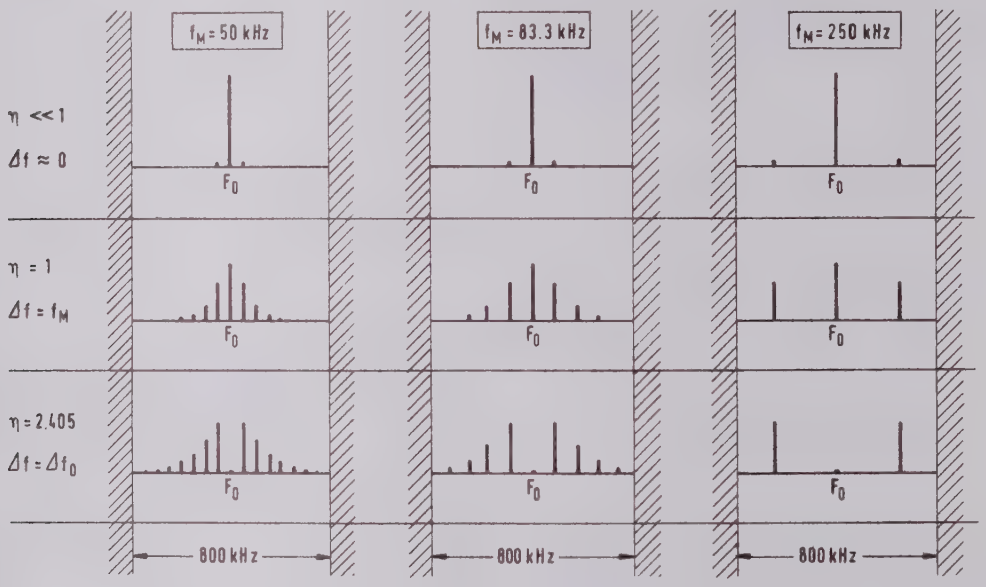


Figure 4-3 "Bessel spectra" as a function of the r.m.s. test deviation Δf (or U_M) at three test frequencies; the frequency-range displayed on the screen of the RME-5 is approximately 800 kHz

4.2.3 USE OF LOW TEST FREQUENCIES

The RM-5 has the low test frequencies of 25 kHz (27.778 kHz) and 50 kHz (55.556 kHz). The importance of these low test frequencies is shown with the aid of two examples.

4.2.3.1 Measurements in narrowband systems

Figure 4-4a shows the group delay $\tau(f)$ of a test object (narrowband system) with bandwidth B, together with the frequency triplet of the sampling FM spectra with the

high test frequency f_{M2} in Figure 4-4b and
low test frequency f_{M1} in Figure 4-4c.

From the ratio of the bandwidth B and sweep deviation ΔF, it can be seen that sufficient exploring is not possible at the high test frequency f_{M2}. The group delay behavior of the system can be displayed with sufficient accuracy only at the smallest test frequency; $B \sim 2\Delta F$.

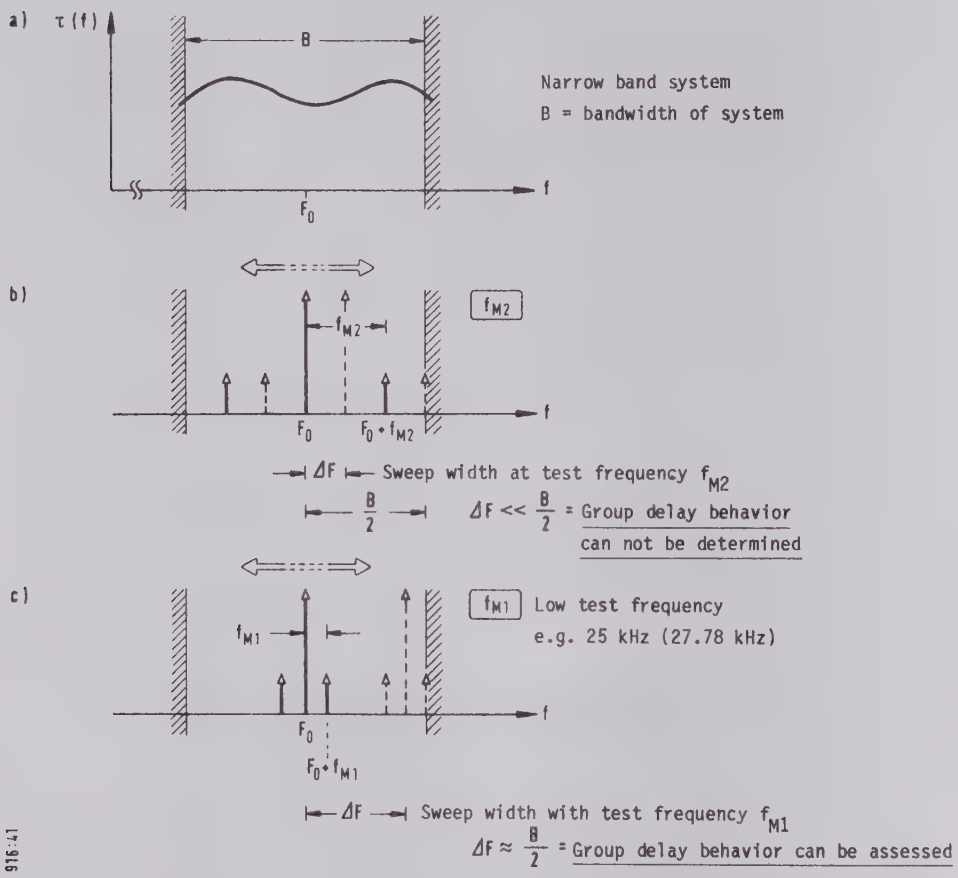


Figure 4-4 Exploring of a narrowband system with "automatic sweep width reduction" active
a) Group delay τ(f)
b) Exploring with high test frequency f_{M2}
c) Exploring with low test frequency f_{M1} ($<<f_{M2}$)

4.2.3.2 Measurements on systems with ripple-shaped transfer functions

Figure 4-5 shows the conditions during exploring of a group delay curve τ(f) with a ripple shape - e.g. surface filter - with two different test frequencies f_{M1} and f_{M2} ($f_{M1} < f_{M2}$).

Figures 4-5 a, b show the explored frequency triplets of the FM spectrum at a given point of the exploration range (B). If the τ values for the various spectral lines are considered - particularly the upper and lower sidelines - different values for the difference $\Delta\tau_1$, $\Delta\tau_2$ at test frequencies f_{M1} and f_{M2} are obvious. The slope "$\Delta\tau/2f_M$" is a dimension for the resolution. The steeper the slope, the better the resolution.

From this example, it is clear that the fine ripple structure in the group delay curve can be resolved only with a very low test frequency (f_{M1}). A test frequency which is too high (f_{M2}) would flatten the curve.

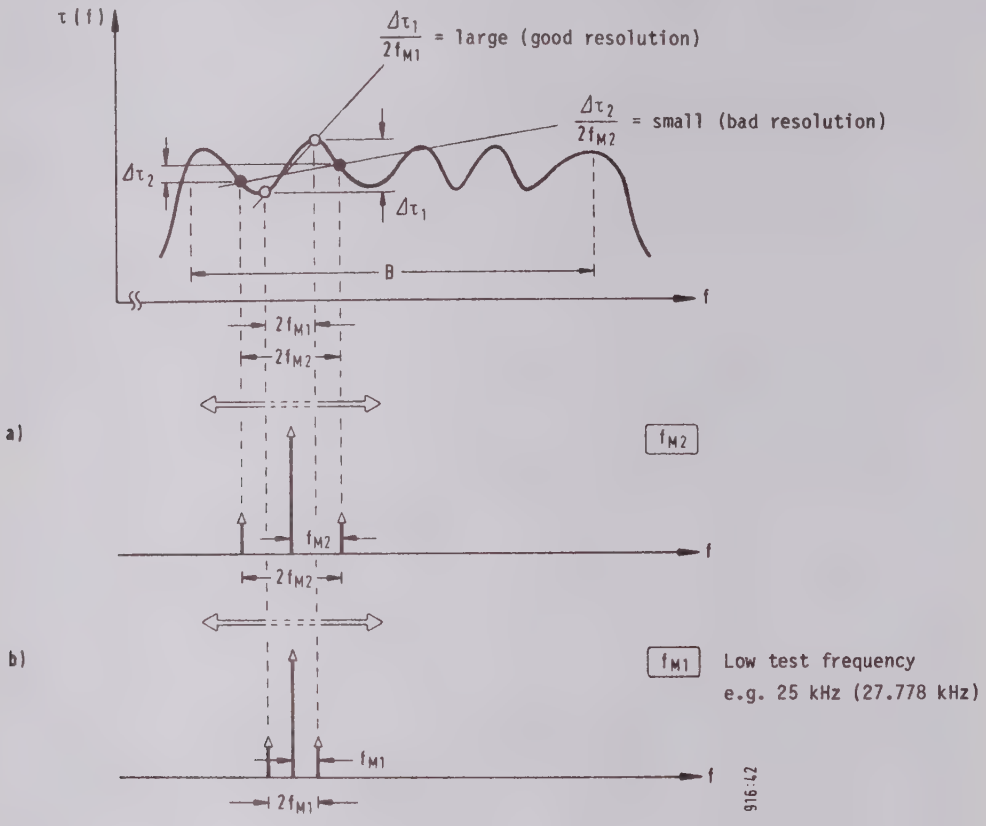


Figure 4-5 Sampling a ripple shaped group delay curve τ(f) (wideband system)
a) with high test frequency f_{M2}
b) with low test frequency f_{M1}

4.3 SUPPRESSION OF NOISE BY AVERAGING

If the Y signals of two sequential sweep passes (Y_i and Y_{i+1}) are averaged, effective noise suppression can be achieved, and is an economical solution with respect to storage location requirements. For a specific frequency point x_n, the averaging can be explained with the following relationship:

$$\overline{Y}_{i+1} = \overline{Y}_i + \frac{Y_{i+1} - \overline{Y}_i}{N}$$

N : selectable averaging factor 2, 4, 8, 16, 32
$\overline{Y}_i$: average value of preceding sweep pass (shown on screen)
Y_{i+1} : current signal value (not displayed on screen)

The new average value $\overline{Y}_{i+1}$ is calculated from the current signal value Y_{i+1} and the preceding average value $\overline{Y}_i \cdot \overline{Y}_{i+1}$ (or the complete curve) is then displayed on the screen. The average value $\overline{Y}_i$ determined in the preceding sweep cycle and used for calculation in turn depends on the preceding cycle (i-1) (etc.); see Figure 4-6.

Noise averaging can be increased further by increasing the value of N (> 2), as the difference $Y_{i+1} - \overline{Y}_i$ approaches zero; the average values of two contiguous sweep passes become equal. The distortion curve becomes smoother.

This method of noise averaging has the advantage that recording occurs after each sweep cycle and vertical shifting of the result over the screen is possible at any time.

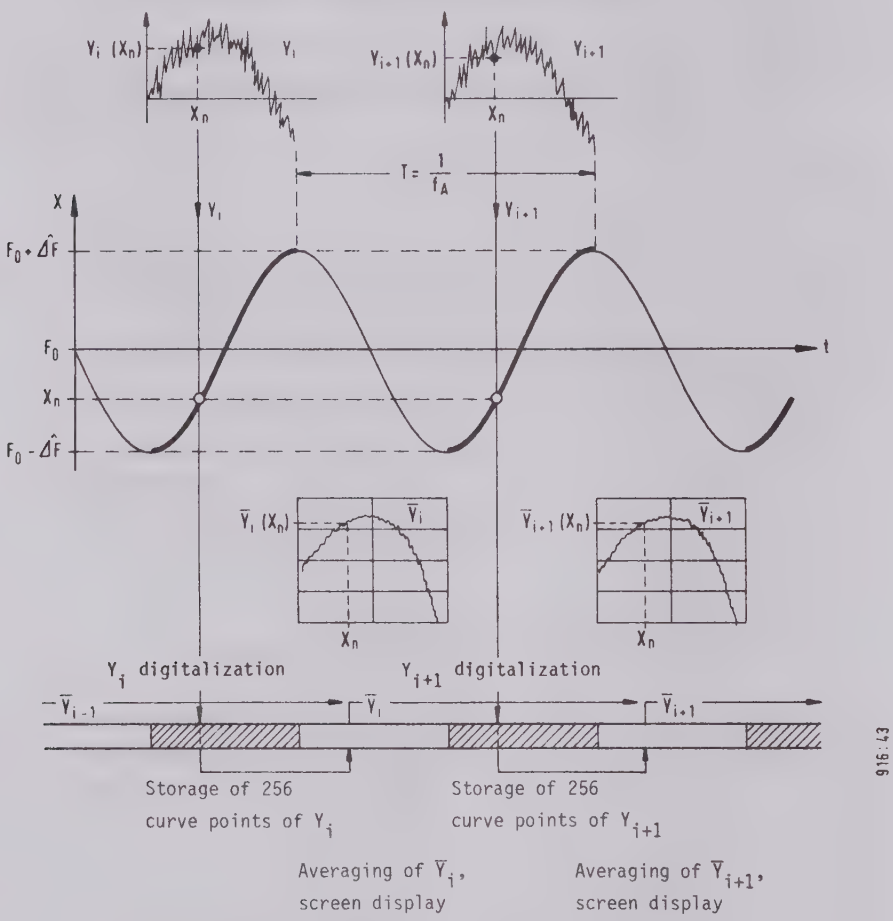


Figure 4-6 Basic timing plan with noise averaging

4.4 USE OF THE RETURN LOSS MEASURING BRIDGE RFZ-4

See also TECHNICAL DATA 1.1.2.7 "IF return loss measurement"

With the aid of the Return Loss Measuring Bridge RFZ-4 (BN 697/00.04), the return loss of coaxial test objects can be measured or swept in the frequency range 10 MHz to 200 MHz. The reference impedance (characteristic impedance) is 75 Ω. With the aid of the Radio-Link Measuring Setup RM-5, return loss measurements can be carried out in the IF ranges 25 to 45 MHz or 45 to 95 MHz. Matching to all common connector types is ensured by the conversion system Versacon® 9.

4.4.1 ERROR LIMITS

The error limits are a function of the directivity ratio D of the bridge and of the measured value a_r. The value D depends on the plug type and the frequency as shown in Figure 4-7.

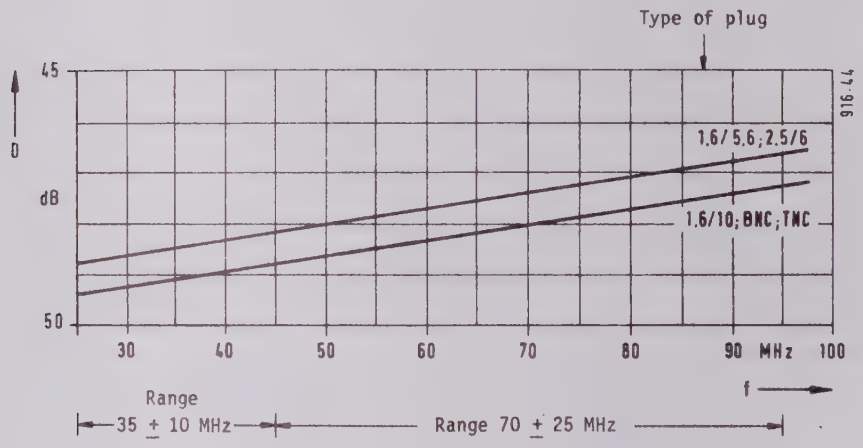


Figure 4-7 Directivity ratio D(f) of the a_r bridge "RFZ-4"
Parameter: type of plug screwed into Versacon connector

The error limits of the a_r measurement (function of a_r and D) are shown in Figure 4-8. A prerequisite for this is calibration of the Mesuring Setup for a_r measurements with a short circuit (r = -1) at the measuring output of the bridge and in the required sweep range. See also Section 3.8.7.2.

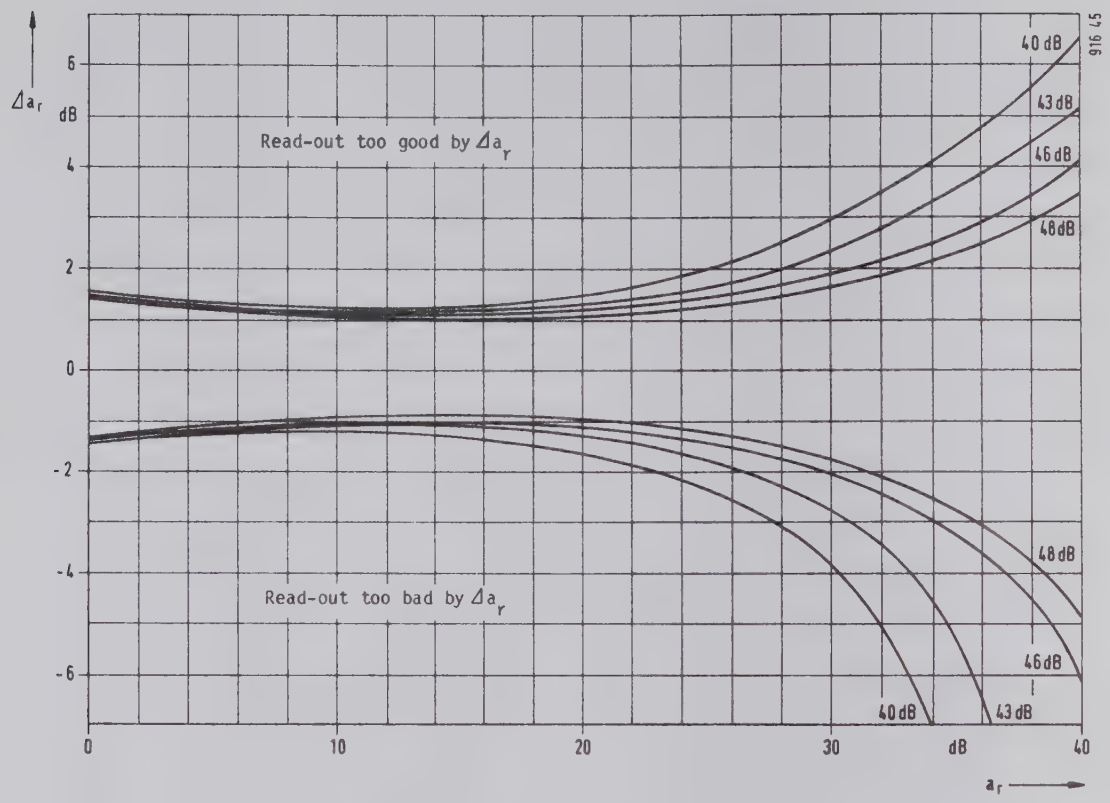


Figure 4-8 Error limits of a_r measurement with the RM-5 after calibration
Parameter: D as shown in Figure 4-7

5 FUNCTIONAL CHECK, MAINTENANCE AND MISCELLANEOUS

5.1 FUNCTIONAL CHECK

Correct operation of the Radio-Link Measuring Setup RM-5 for the most important applications can be checked by back-to-back operation of the Generator and Receiver (Section 5.1.2). The "functional check" is intended to check the characteristics shown in the Specifications and the compliance with the error limits. The equipment settings specified in the various sections are not necessarily the worst case for which the error limits are still valid. For the back-to-back measurements, the short, double screened 75 Ω cable which is supplied with the instrument should be used.

If the RME-5 is equipped with the XY plotter interface, or if a video printer is available, we recommend that the results be recorded.

In order to determine which instrument is responsible for any error which is detected, the most important characteristics of the Generator should be checked with the aid of additional instruments (calibrated level meter and frequency counter). These measurements precede the back-to-back measurements (Section 5.1.1).

Note: Measurements should be carried out after a warming up period of $\geq$ 30 minutes. As the internal measuring and sweep frequencies are used for the functional check, switch [34] on the rear of the RMS-5 must be left in the position "INT.".

5.1.1 CHECKING THE RMS-5 GENERATOR

5.1.1.1 IF output level

Required test equipment: calibrated level meter (e.g. EPM-1 with Probe TK-10 from W & G)

Settings on the RMS-5:

[2] : 0 dB [4] : 70 MHz (35 MHz if Option fitted)
[13] : 0 dBm [16] : 0 mV (0 kHz) [7] : $\hat{\Delta}$F = 0

All other controls can be set to any position.

- Calibrate the calibrated level meter to 0 dBm at Z_{out} = 75 Ω
- Connect the calibrated level meter to socket [1]
- Required indication on level meter: 0 dBm $\pm$ 0.2 dB
- Move switch [4] to position "35 MHz" if 35 MHz IF (Option) is fitted
- Required indication on level meter: 0 dBm $\pm$ 0.2 dB

5.1.1.2 BB output level

Test voltage U_M

Required test equipment: calibrated level meter (e.g. EMP-1 with Probe TK-10 from W & G)

Settings on the RMS-5:

[15]: Pushbuttons not depressed
[16]: 0 dBm ($\cong V_{rms} \cong$ 274 mV)
[17]: 0 V
[8] : Pushbutton "0.093" or "0.083"

Position of all other controls optional.

- Calibrate the calibrated level meter to 0 dBm at Z_{out} = 75 Ω
- Connect the calibrated level meter to socket [14]
- Required indication on calibrated level meter: 0 dBm ± 0.7 dB
- Call-up all test frequencies under [8] and [9] in turn
- Required indication on calibrated level meter in each case: 0 dBm ± 0.7 dB

S w e e p v o l t a g e U_A

Required test equipment: calibrated level meter (e.g. EPM-1 with probe TK-10 from W & G)

Settings on the RMS-5

[15]: Pushbuttons not depressed [20]: 70 Hz
[16]: - ∞ dBm (≙ 0 mV)
[17]: 0 V

Positions of all other controls optional.

- Calibrate the calibrated level meter to 0 dBm at Z_{out} = 75 Ω
- Connect the calibrated level meter in series with a 9.03 dB attenuator (accessory for EPM-1) to socket [14]
- Increase sweep voltage $\hat{U}_A$ with potentiometer [17] until the calibrated level meter indicates 0 dBm
- Potentiometer [17] must now be in the position 1.1 ± 0.12 V

5.1.1.3 IF center frequencies and IF center frequency offset[1)]

Required test equipment: frequency counter up to 2 MHz

Settings on the RMS-5:

[4]: 70 MHz (35 MHz if Option fitted)
[7]: "$\hat{\Delta}$F = 0"

Positions of all other controls optional.

- Connect the frequency counter to socket [31] on the rear of the RMS-5
- Required display on frequency counter (after calibration of IF, see Section 3.6.3): 700 KHz ± 0.5 kHz
- Turn switch [4] to position "VARIAB ± 25 MHz"
- Turn the 10-turn helical potentiometer [3] to the following positions and observe the display on the frequency counter

1) For frequency measurements in accordance with Section 5.1.1.3, the IF counter of the RME-5 can be used. Establish connection [1] RMS-5 to [25] RME-5

Position	Display on frequency counter	Tolerance
0	450 kHz	± 2.5 kHz
1	500 kHz	
2	550 kHz	
3	600 kHz	
4	650 kHz	
5	700 kHz	
6	750 kHz	
7	800 kHz	
8	850 kHz	
9	900 kHz	
10	950 kHz	

- Set switch [4] to position "VARIAB ± 12.5 MHz"
- Turn the 10-turn helical potentiometer [3] to the following positions and observe the display on the frequency counter

Position	Display on frequency counter	Tolerance
0	225	± 1.25 kHz
1	250	
2	275	
3	300	
4	325	
5	350	
6	375	
7	400	
8	425	
9	450	
10	475	

5.1.1.4 Test frequencies and sweep frequency

Required test equipment: frequency counter up to 20 MHz

Settings on the RMS-5:

[15]: Not depressed

[16]: > -10 dBm (> 85 mV)

[7] : Position $\hat{U}_A = 0$

[19]: 70 Hz

Positions of all other controls optional.

- Connect the frequency counter to socket [14]
- Call-up all measuring frequencies with pushbuttons [8], [9]

Pushbutton [8]		Display/kHz		Permissible deviation
Series I	Series II	Series I	Series II	
0.027	0.025	27.778	25.000	$\pm 2 \times 10^{-5} f_M$
0.055	0.05	55.556	50.000	
0.092	0.083	92.593	83.300	
0.277	0.25	277.778	250.000	
0.555	0.5	555.556	500.000	
Pushbutton [9]				
2.4		2400.00		
5.6		5600.00		

- Turn potentiometer [16] to "$-\infty$ dBm", switch [7] to position "$\hat{\Delta}$F", potentiometer [18] to > 0 V
- Display on frequency counter = 0.070 kHz $\pm$ 0.0014 kHz
- Turn switch [19] to position "18 Hz"
- Display on frequency counter = 0.018 $\pm$ 0.00036 kHz

5.1.2 CHECKING THE RM-5 MEASURING SET-UP WITH RMS-5 and RME-5 CONNECTED BACK-TO-BACK

5.1.2.1 BB - BB distortion measurement including automatic test frequency tuning

Settings on the RMS-5:		Pushbuttons on the RME-5:	
[15]:	Not depressed	[23]:	"BB measurement"
[16]:	-10 dBm ($\cong$ 84 mV)	[2] :	"$\Delta\tau$,$\Delta\varphi$" measuring range: $\leq$ 0.2 ns/D or 0.1% rad/D
[17]:	1 V		
[8] :	"0.555" (or "0.5")	[10]:	"$\Delta U/U_o$", measuring range = 0.1 %/D
[18]:	70 Hz		

- Connect socket [14] of the RMS-5 to socket [27] of the RME-5
- Adjust potentiometers [1] and [9] (RME-5) so that the results "$\Delta\tau$" and "$\Delta U/U_o$" are visible
- Assess the result and switch to a higher test frequency
- Depress the 20 dB pushbutton "U_M" of [15] on the RMS-5 and repeat the above operation

Permitted intrinsic noise (peak-to-peak), averaging factor 32

$\Delta\tau$(at 556 kHz or 500 kHz)	$\Delta U/U_o$, $\Delta\varphi$/rad
$\leq$ 0.1 ns	$\leq$ 0.05 %

When the test frequencies are switched with pushbuttons [8] and [9] of the RMS-5, check the test frequency values displayed in the top line of the screen.

5.1.2.2 IF-IF distortion measurement

Settings on the RMS-5:		Pushbuttons on the RME-5:	
[2] :	0 dBm	[22]:	IF measurement
[13]:	0 dBm	[21]:	70 MHz (or 35 MHz)
[4] :	70 MHz (or 35 MHz)	[2] :	"$\Delta\tau, \Delta\varphi$", measuring range $\leq$ 0.2 ns/D or 0.1 % rad/D
[6] :	12 MHz		
[7] :	Position "$\Delta\hat{F}$"	[10]:	"$\Delta U/U_o$", measuring range = 0.1 %/D
[16]:	500 kHz		
[20]:	70 Hz		
[8] :	"0.555" or "0.5"		

- "Automatic sweep width reduction" switched off
- Connect socket [1] of the RMS-5 to socket [25] of the RME-5
- Adjust potentiometers [1] and [9] of the RME-5 so that the results $\Delta\tau$, $\Delta\varphi$ and $\Delta U/U_o$ are visible
- First measurement: 70 MHz $\pm$ 12 MHz
- Second measurement: 70 MHz $\pm$ 25 MHz
  Necessary new setting on RMS-5: [6] : 25 MHz
- Third measurement: 35 MHz $\pm$ 5 MHz
  Necessary new settings: on RMS-5: [4] : 35 MHz
  [6]: 5 MHz
  on RME-5: [21]: 35 MHz
- Fourth measurement: 35 MHz $\pm$ 10 MHz
  Necessary new setting on RMS-5: [6] : 10 MHz
- Checking of the intrinsic impairments is to be carried out at a measuring frequency of 277 kHz (or 250 kHz) and a measuring frequency of > 1 MHz.

Permitted intrinsic distortion:

IF	$\Delta\hat{F}$	f_M < 1 MHz		f_M > 1 MHz	
		$\Delta\tau$ [1]	$\Delta U/U_o$	$\Delta\varphi$	$\Delta U/U_o$
70 MHz	$\pm$ 12 MHz	$\leq$ 0.4 ns	$\leq$ 0.1 %	$\leq$ 0.5 % rad	$\leq$ 0.2 %
	$\pm$ 25 MHz	$\leq$ 1.0 ns	$\leq$ 0.3 %	$\leq$ 1.0 % rad	$\leq$ 0.4 %
35 MHz	$\pm$ 5 MHz	$\leq$ 0.5 ns	$\leq$ 0.2 %		
	$\pm$ 10 MHz	$\leq$ 2.0 ns	$\leq$ 0.8 %		

Permitted intrinsic noise (peak-to-peak), averaging factor 32:
at f_M = 555 or 500 kHz = $\Delta\tau \leq$ 0.1 ns; $\Delta U/U_o \leq$ 0.05 %
at f_M > 1 MHz and Δf = 500 kHz: $\Delta\varphi \leq$ 0.05 % rad; $\Delta U/U_o \leq$ 0.05 %
- If XY plotter interface is fitted or video printer is available, record the results.

1) at 555 or 500 kHz

5.1.2.3 IF frequency response measurement ΔP_I and ΔP_{II}

I F F r e q u e n c y r e s p o n s e ΔP_I (SLOPE CONTROL [19] switched off)

Settings on the RMS-5		Pushbuttons on the RME-5	
[2] :	-10 dBm	[22]:	IF
[13]:	-10 dBm	[21]:	70 MHz (corresponding LED on)
[4] :	70 MHz	[2] :	or
[16]:	$-\infty$ dBm	[10]:	"ΔP_I", measuring range: 0.1 dB/D (⇩ pushbutton)
[7] :	Position "$\hat{\Delta}$F"		
[6] :	25 MHz		
[19]:	70 MHz		

- Connect socket [1] of the RMS-5 (with the short cable) to socket [25] of the RME-5
- Adjust potentiometer [1] (with ΔP_I selected on [2]) until the result is on the centerline of the screen
- Permitted frequency response ΔP_I for 70 MHz ± 25 MHz: ± 0.1 dB
- New settings on the RMS-5 / on the RME-5
  - [4] : 35 MHz — [21]: 35 MHz (corresponding LED on)
  - [6] : 10 MHz
- Permitted frequency response ΔP_I for 35 MHz ± 10 MHz: ± 0.35 dB

IF F r e q u e n c y r e s p o n s e ΔP_{II}

Settings in Section 5.1.2.3 remain unchanged with the exception of RME-5 [2] or [10]: ΔP_{II}, measuring range: 2 dB/D (pushbutton ⇩)

- Connect socket [1] of the RMS-5 to socket [26] of the RME-5
- Connect socket [10] of the RMS-5 to socket [25] of the RME-5
- Adjust potentiometers [1] or [9] until the result is on the centerline of the screen
- Frequency response ΔP_{II} at 70 MHz ± 25 MHz must not be visible
- New settings on RMS-5: / on RME-5:
  - [4] : 35 MHz — [21]: 35 MHz (corresponding LED on)
  - [6] : 10 MHz
- Frequency response ΔP_{II} at 35 MHz ± 10 MHz must not be visible

5.1.2.4 IF level and r.m.s. value test frequency deviation measurement, including calibration

- Calibrate the instrument as described in Section 3.6.4

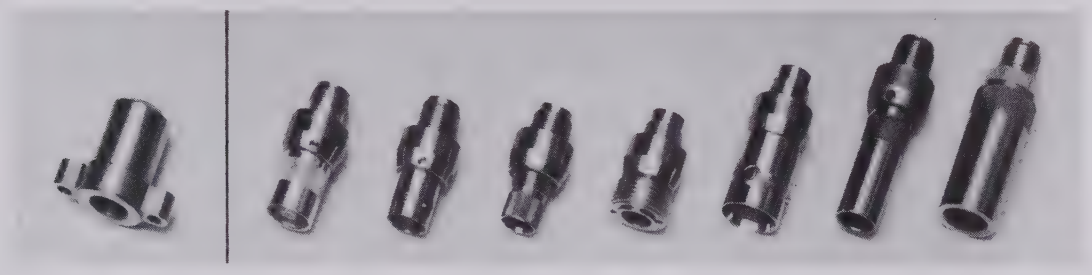
Check of r.m.s. value deviation display:

- Select test frequency on RMS-5 with pushbutton "0.093" [8] (or "0.083")
- Depress pushbutton [3] "BESSEL SPECT" on RME-5
- Increase U_M from 0 V with potentiometer [16] on the RMS-5 until the first Bessel null position is reached
- RMS value deviation display Δf = 157 kHz (or 142 kHz), exactly 1 kHz is displayed

Check of level display:
- Turn switch [13] on RMS-5 to position "-10 dBm"
- Select on RME-5 (pushbutton [4]) ΔP_I display -10 dBm $\pm$ 0.2 dB
- Turn switch [13] on RMS-5 to position "-20 dBm"
- ΔP_I display on RME-5: -20 dBm $\pm$ 0.2 dB

5.2 UNIVERSAL CONNECTOR "VERSACON® 9"

The coaxial signal-inputs and -outputs are equipped with the universal connector "Versacon®9" made by Wandel & Goltermann (Figure 5-1). This permits rapid conversion without soldering to any of the connectors mentioned below. The required adapter is screwed into the universal socket with the assembly wrench (in the accessory box on the rear of the instrument).



Versacon® 9 Lemo BNC 1.6/5.6 2.5/6 1.6/10 558A 470C Western Electric

Figure 5-1 Basic connector "Versacon®9" with some of the available adapters

5.3 MAINTENANCE AND MISCELLANEOUS

The Radio-Link Measuring Setup RM-5 requires no special maintenance provided it is treated correctly. The closed case protects the circuits even during transport. We recommend the use of Protective Covers SD-3 (RMS-5)and SD-6 (RME-5) in order to protect the controls on the front panel and the sockets on the rear of the instrument against water spray, dust, and mechanical damage. In addition, the instruments can then be carried with the carrying handle of the Protective Covers.

In the case of long distance shipping or rough transport, we recommend the use of the Equipment Transport Cases TPK-3 (RMS-5) and TPK-6 (RME-6) (See Section 3.1.2).

5.4 MECHANICAL CONSTRUCTION

⚠ Caution: Before opening the instruments, disconnect the mains plug from the power outlet. The instrument must be switched off whenever assemblies or Options are inserted or removed.

The case dimensions comply with DIN Standard 41 494 and the American standard ASA C 83.9. This means that the instrument can be installed in 19" racks (see Section 3.2.2). The covers, base, and side walls are made of robust cast aluminum, screwed together with two times 6 Allen head screws.

Use the enclosed Allen wrench, which is carried in the accessory box on the rear of the instrument, for loosening the screws.

For this operation, the RMS-5 is best laid on the right side wall with the power supply unit. After loosening of the screws and removal of the case components, the equipment chassis with the printed circuit boards is accessible. The chassis can be removed from the right side wall for repair work if the cable connections to the power supply unit are disconnected.

In the case of the RME-5, the complete chassis including front panel and rear wall can be lifted out of the case after removing the top cover.

Note that the chassis is connected to the power supply unit on the right wall of the case.

As all important assemblies of the analog and digital section (printed circuit boards) are arranged vertically from the rear of the instrument (see Figure 5-2), we recommend that the chassis be left in the case during replacement of a printed circuit board and only the rear wall removed. The appropriate board can be pulled out of the instrument.

Detailed description of stripping work is provided in the Service Handbook.

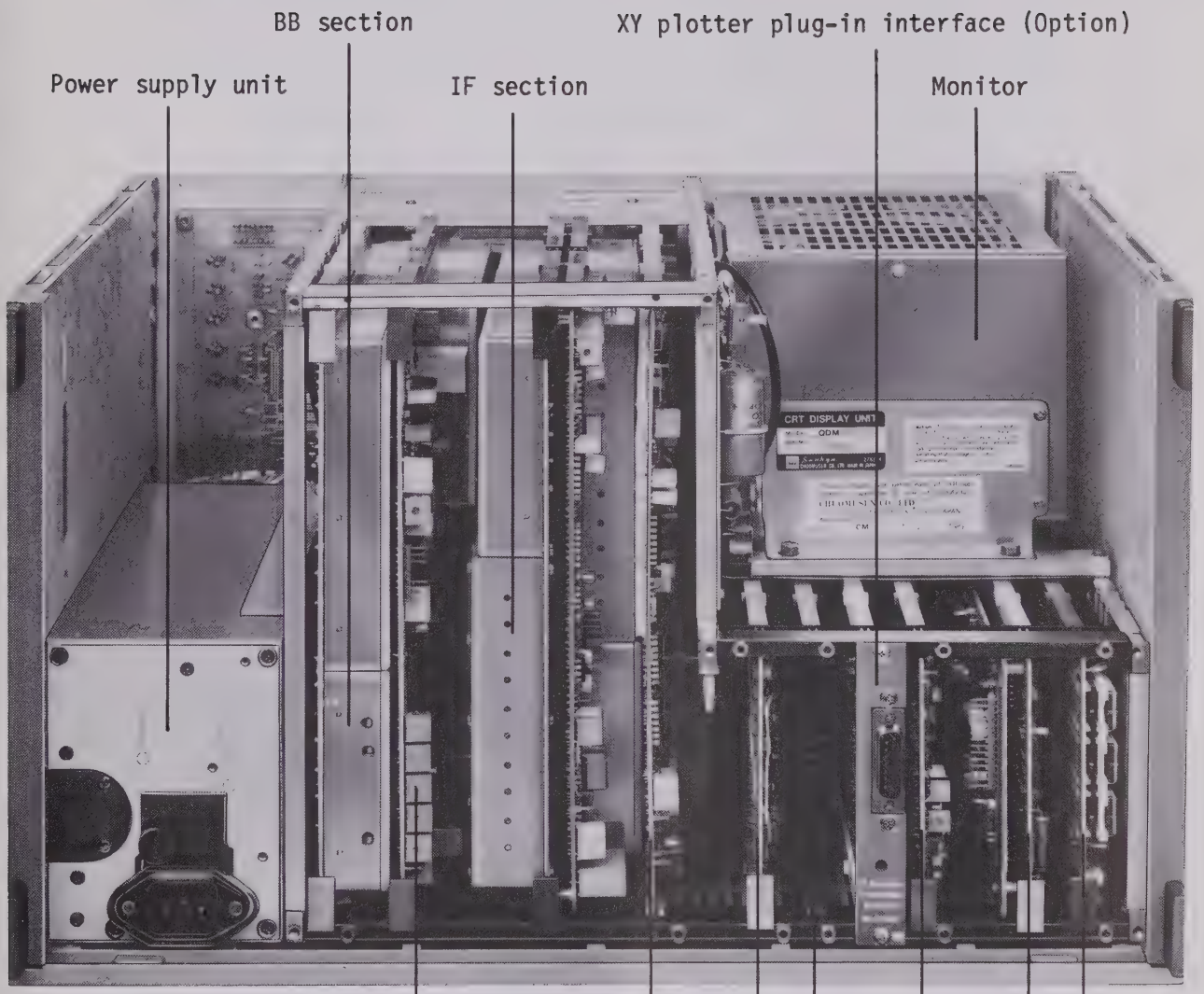


Figure 5-2 Arrangement of assemblies of the RME-5 (rear view, without cover)

5.5 REPLACEMENT OR INSTALLATION OF INTERFACE BOARDS

The printed circuit boards for the Interface Bus <IEC 625>, BN 853/07, and XY plotter interface BN 917/00.01 are installed from the rear of the instrument (see Figure 3-4b). After the two outer screws have been removed, the insertion compartment is accessible and the board can be replaced. The interface board is then retained with the two screws.

5.5.1 XY PLOTTER INTERFACE BN 917/00.01

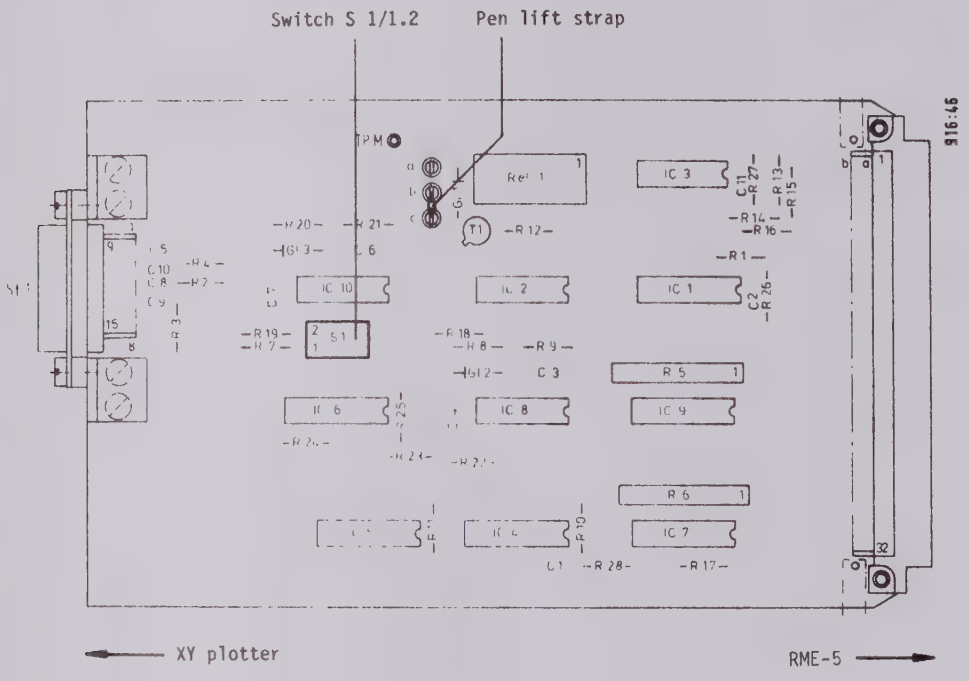


Figure 5-3 XY plotter interface with switch S 1/1, 2 and pen-lift strap

5.5.2 <IEC 625> INTERFACE BN 853/07

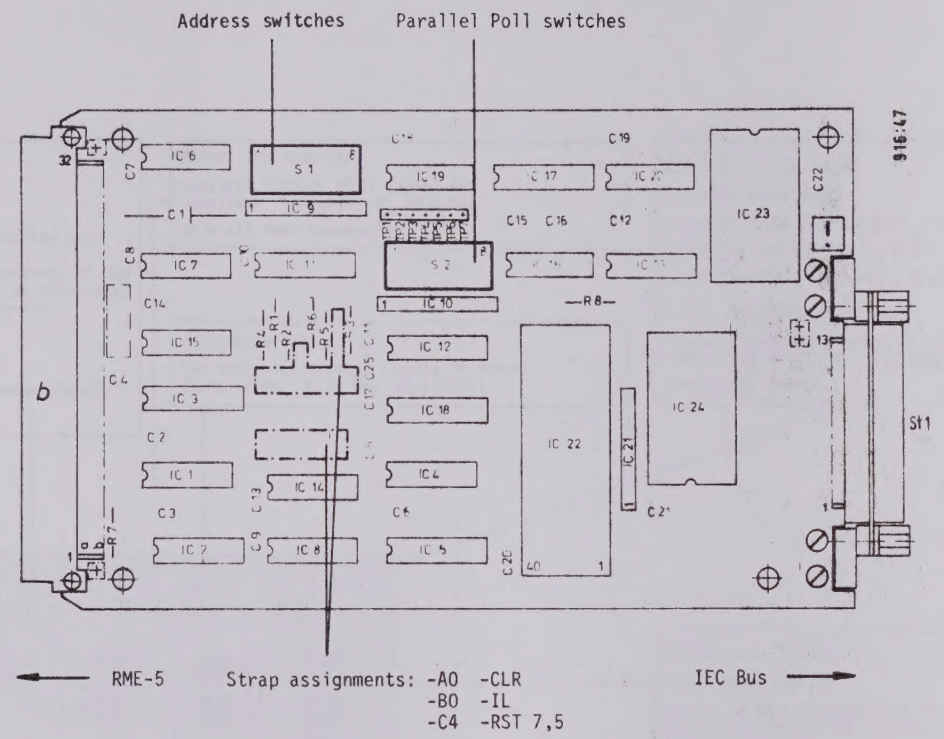


Figure 5-4 <IEC 625> Interface board with Address and Parallel Poll switches

MP MASTER
MA29311

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